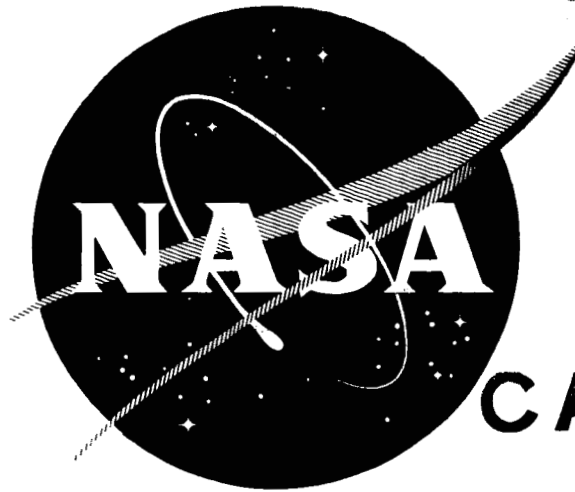


N 73 27584



NASA CR-121181

WANL-M-FR-73-002

**CASE FILE
COPY**

FINAL REPORT

**FABRICATION OF CAPSULE ASSEMBLIES
PHASE III**

BY

A. R. KEETON AND L. G. STEMANN

WESTINGHOUSE ASTRONUCLEAR LABORATORY

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA LEWIS RESEARCH CENTER

CONTRACT NAS 3-15332

NOTICE

This report was prepared as an account of Government-sponsored work. Neither the United States, nor the National Aeronautics and Space Administration (NASA), nor any person acting on behalf of NASA:

- A.) Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights; or
- B.) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

As used above, "person acting on behalf of NASA" includes any employee or contractor of NASA, or employee of such contractor, to the extent that such employee or contractor of NASA or employee of such contractor prepares, disseminates, or provides access to any information pursuant to his employment or contract with NASA, or his employment with such contractor.

Requests for copies of this report should be referred to

National Aeronautics and Space Administration
Scientific and Technical Information Facility
P. O. Box 33
College Park, Maryland 20740

1. Report No. NASA CR-121181		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Fabrication of Capsule Assemblies - Phase III				5. Report Date March, 1973	
				6. Performing Organization Code	
7. Author(s) A. R. Keeton and L. G. Stemann				8. Performing Organization Report No. WANL-M-FR-73-002	
9. Performing Organization Name and Address Westinghouse Astronuclear Laboratory P. O. Box 10864 Pittsburgh, Pa. 15236				10. Work Unit No.	
				11. Contract or Grant No. NAS 3-15332	
				13. Type of Report and Period Covered Contractor Report	
12. Sponsoring Agency Name and Address National Aeronautics & Space Administration Washington, D. C.				14. Sponsoring Agency Code	
15. Supplementary Notes R. J. Galbo, Project Manager NASA Lewis Research Center Cleveland, Ohio 44135					
16. Abstract <p>Thirteen capsule assemblies were fabricated for evaluation of fuel pin design concepts for a fast spectrum lithium cooled compact space power reactor. These instrumented assemblies were designed for real time test of prototype fuel pins. Uranium mononitride fuel pins were encased in AISI 304L stainless steel capsules. Fabrication procedures were fully qualified by process development and assembly qualification tests. Instrumentation reliability was achieved utilizing specially processed and closely controlled thermocouple hot zone fabrication and by thermal screening tests. Overall capsule reliability was achieved with an all electron beam welded assembly.</p>					
17. Key Words (Suggested by Author(s)) T-111 Uranium Nitride Instrumented Fuel Pins				18. Distribution Statement Unclassified - unlimited	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 127	
				22. Price*	

* For sale by the National Technical Information Service, Springfield, Virginia 22151

FOREWORD

The work described herein was done at the Astronuclear Laboratory, Westinghouse Electric Corporation, under NASA Contract NAS 3-15332 with Mr. Robert J. Galbo, NASA-Lewis Research Center, Plum Brook Station, as Project Manager. Mr. A. R. Keeton was Project Manager for Westinghouse Electric Corporation, while Mr. L. G. Stemann was responsible for overall supervision and weld development as required.

TABLE OF CONTENTS

<u>Section</u>		<u>Page No.</u>
1.0	SUMMARY	1
2.0	INTRODUCTION	2
3.0	CAPSULE ASSEMBLY	3
4.0	THERMOCOUPLE ASSEMBLIES	17

APPENDIXES

A	Thermocouple Assembly Fabrication Procedures	A-1
B	Capsule Assembly Fabrication Procedures	B-1
C	Pre-Irradiation Capsule Data	C-1
D	Welding and Soldering	D-1
E	T-111, Ta, Mo and Stainless Steel Cleaning Procedures	E-1
F	Tools and Containers Cleaning Procedures	F-1
G	Capsule Assembly Packaging and Shipping Procedures	G-1
H	Tube to End Cap Weld Cracking Analysis and Repair Development	H-1
I	Thermocouple Well Contamination	I-1
J	Capsule Rust Investigation	J-1

LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
1	D Size L/3 and L Length Prototype Capsule Assemblies (PF-10650)	4
2	D Size L Length Instrumented Capsule Assemblies (PF-10651)	5
3	L-Instrumented Capsule Parts Before Assembly	8
4	L-Prototype Capsule Ready for Final Assembly	9
5	L-Instrumented Capsule Completely Constructed	10
6	L/3 Capsule Completely Constructed	11
7	Weld Location Schematic - L/3 Capsule	13
8	Weld Location Schematic - L-Instrumented Capsule	14
9	Weld Location Schematic - L-Prototype Capsule	15
10	Drawing of Wall, End Cap, and Fuel Center Thermocouple	18
11	Controlled Atmosphere Thermocouple Transfer Container with Thermocouple	20
12	Controlled Atmosphere Thermocouple Transfer Container Separated at "O" Ring Seal	21
13	Thermocouple Bake Out and Assembly Chamber	23

LIST OF TABLES

<u>Table No.</u>		<u>Page No.</u>
1	Hardware Detail	6
2	Capsule Thermocouple Information	18

1.0 SUMMARY

Capsule assemblies fabricated in this program were designed by the Plum Brook Station of NASA-Lewis Research Center for evaluation of fuel pin design concepts for a fast spectrum lithium-cooled compact space power reactor. These assemblies consisted of T-111 (Ta-8W-2Hf) clad, tungsten lined uranium mononitride fuel pins encased in stainless steel capsule assemblies and were designated as Phase III capsules. The fuel pins were fabricated previously under Contract NAS 3-14415. Design uniform clad temperature is achieved by a stepped, annular, helium filled space between the fuel pin and capsule. Double encapsulation was provided throughout, even for the centerline thermocouple penetrations.

Assembly procedures and construction techniques were fully qualified, and complete documentation was maintained for each assembly. Thermocouples were constructed to very detailed procedures, controlling every aspect of fabrication, handling, and storage. Capsule assemblies were completely constructed by electron beam welding and sealed in high purity helium by arc welding a closure hole. Thorough inspection and quality assurance techniques were utilized to assure assemblies of the highest quality.

2.0 INTRODUCTION

An in-pile testing program is being performed by NASA Plum Brook Reactor Facility as part of the development of a fast spectrum reactor. These tests will demonstrate the feasibility of fuel pin design and serve to evaluate the effects of variable power density, burnup, and irradiation time on fuel pin performance.

This contract provides for the encapsulation of Phase III fuel pins produced under Contract NAS 3-14415 *. These are full size prototype and reduced length fuel pins for conducting real time tests. Experience obtained in Phases I and II reported in NASA Contract report CR-72905 and CR-120788 was utilized where applicable.

This report summarizes the details of hardware fabricated in this program with cross references to drawings and assembly procedures. Capsule descriptions and drawings are presented along with salient features of assembly and procedural information. Detailed assembly sequences, cleaning, handling, and welding procedures are appended.

* Keeton, A. R. and L. G. Stemann, "Fabrication of Fuel Pin Assemblies-Phase III", NASA CR-120956, December, 1972

3.0 CAPSULE ASSEMBLY

Capsule assemblies in this program were constructed to three basic configurations (Figures 1 and 2). These drawings were designated as "L" prototype, "L" instrumented, and the L/3 capsules.

Drawing nomenclature is used in the discussion throughout this report. The hardware produced is summarized in Table 1.

Capsule assembly procedures and fabrication techniques are described in general in this section of the report, while detailed step by step assembly and inspection procedures are included in the following appendices:

- A. Thermocouple Assembly Fabrication Procedures
- B. Capsule Assembly Fabrication Procedures
- C. Pre-Irradiation Capsule Data Procedures
- D. Welding and Soldering
- E. T-111, Ta, Mo, and Stainless Steel Cleaning Procedures
- F. Tools and Containers Cleaning Procedures
- G. Capsule Assembly Packaging and Shipping Procedures.

Completed procedure sheets from Appendixes A, B, and C were supplied to NASA for each piece of hardware delivered. Appendixes D, E, and F are guides for specific processes.

The capsule is a closely sized cylindrical tube with welded end caps constructed from AISI 304L stainless steel. Its purpose is to contain and protect the T-111 clad fuel pin during reactor testing. The fuel pin ends are designed to mate with the capsule end caps to achieve concentricity with the capsule tube and to allow for differential thermal expansion. The capsule wall has a stepped configuration to achieve uniform fuel pin clad temperature

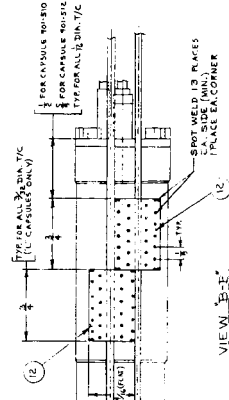


Figure 2. D Size L Length Instrumented Capsule Assembly

TABLE 1. HARDWARE DETAILS

CAPSULE NUMBER	DRAWING NUMBER	REV.	TYPE	STYLE	CRITICAL ANNULAR GAP mm Inches	DISPOSITION
901-603	PF-10651	A	L-Instrumented (practice)	X	1.07 (.0420)	Delivered to NASA for component setup purposes
901-510A	PF-10651	A	L-Instrumented	X	.96 (.0377)	Delivered to NASA for reactor testing
901-510B	PF-10651	A	L-Instrumented	X	---	Final Assembly not made due to program cancellation
901-512A	PF-10650	A	L-Prototype	X	.98 (.0386)	Delivered to NASA for reactor testing
901-512B	PF-10650	A	L-Prototype	X	.97 (.0382)	Delivered to NASA for reactor testing
901-512C	PF-10650	A	L-Prototype	X	.97 (.0382)	Delivered to NASA for reactor testing
901-514A	PF-10650	A	L/3	X	.92 (.0363)	Delivered to NASA for reactor testing
901-514A	PF-10650	A	L/3	X	.92 (.0361)	Delivered to NASA for reactor testing
901-514C	PF-10650	A	L/3	X	.91 .0359	Delivered to NASA for reactor testing
901-516A	PF-10650	A	L/3	Y	---	Final assembly not made due to program cancellation
901-516B	PF-10650	A	L/3	Y	---	Final assembly not made due to program cancellation
901-516C	PF-10650	A	L/3	Y	---	Final assembly not made due to program cancellation
901-518A	PF-10650	A	L/3	Y	.97 (.0381)	Delivered to NASA for reactor testing
901-518B	PF-10650	A	L/3	Y	.97 (.0382)	Delivered to NASA for reactor testing
901-522		A	L/3	dummy	---	Delivered to NASA

and the annular gap between the fuel pin and capsule is designed for a specific heat removal rate. Ultra-pure helium is contained at atmospheric pressure between the fuel pin and capsule.

Chromel-alumel thermocouples are used to monitor the fuel pin temperature from positions in the end caps and wells that extend axially through the center of the fuel pellets. Additional thermocouples are attached to the capsule wall to monitor power generation and serve as backup instrumentation in the event that the other thermocouples should fail.

Stringent cleanliness standards were employed for component preparation and assembly. Final cleaning was performed as near to assembly time as practical to minimize storage time and handling after cleaning. Precautions were also taken to assure that tools, containers, and handling equipment were cleaned before contacting capsule parts.

A layout of "L" instrumented capsule parts is shown in Figure 3 and "L" prototype parts in Figure 4. The normal assembly sequence consists of constructing thermocouple and well subassemblies, welding thermocouple subassemblies into the end caps, then assembling fuel pin capsule tube and end caps.

In performing the final capsule assembly, the T-111 fuel pin was wrapped with Ta foil for insertion into the stainless steel capsule tube. This was a precaution to prevent metallic contamination of the T-111 alloy, which is incompatible with stainless steel (even in trace amounts) at elevated temperature. The tantalum foil was removed prior to sliding the end caps into place.

End caps were electron beam welded in position, and the vent hole sealed by GTA welding. Installation of sheathed thermocouples in capsule wall slots completed the assembly process. Figures 5 and 6 are completed capsule assemblies.

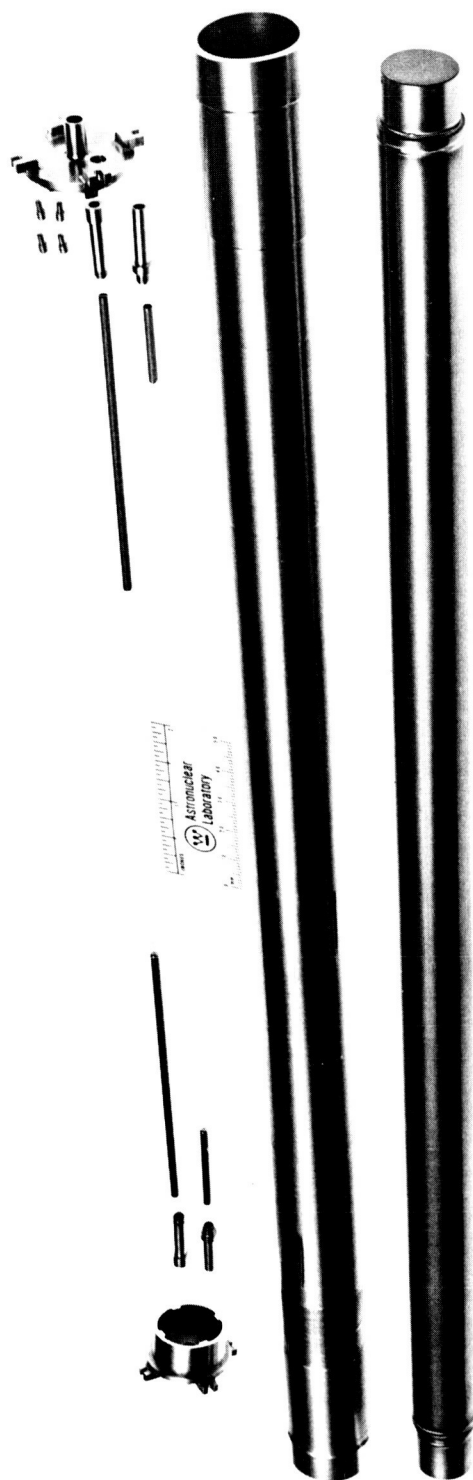


Figure 3. L-Instrumented Capsule Parts Before Assembly

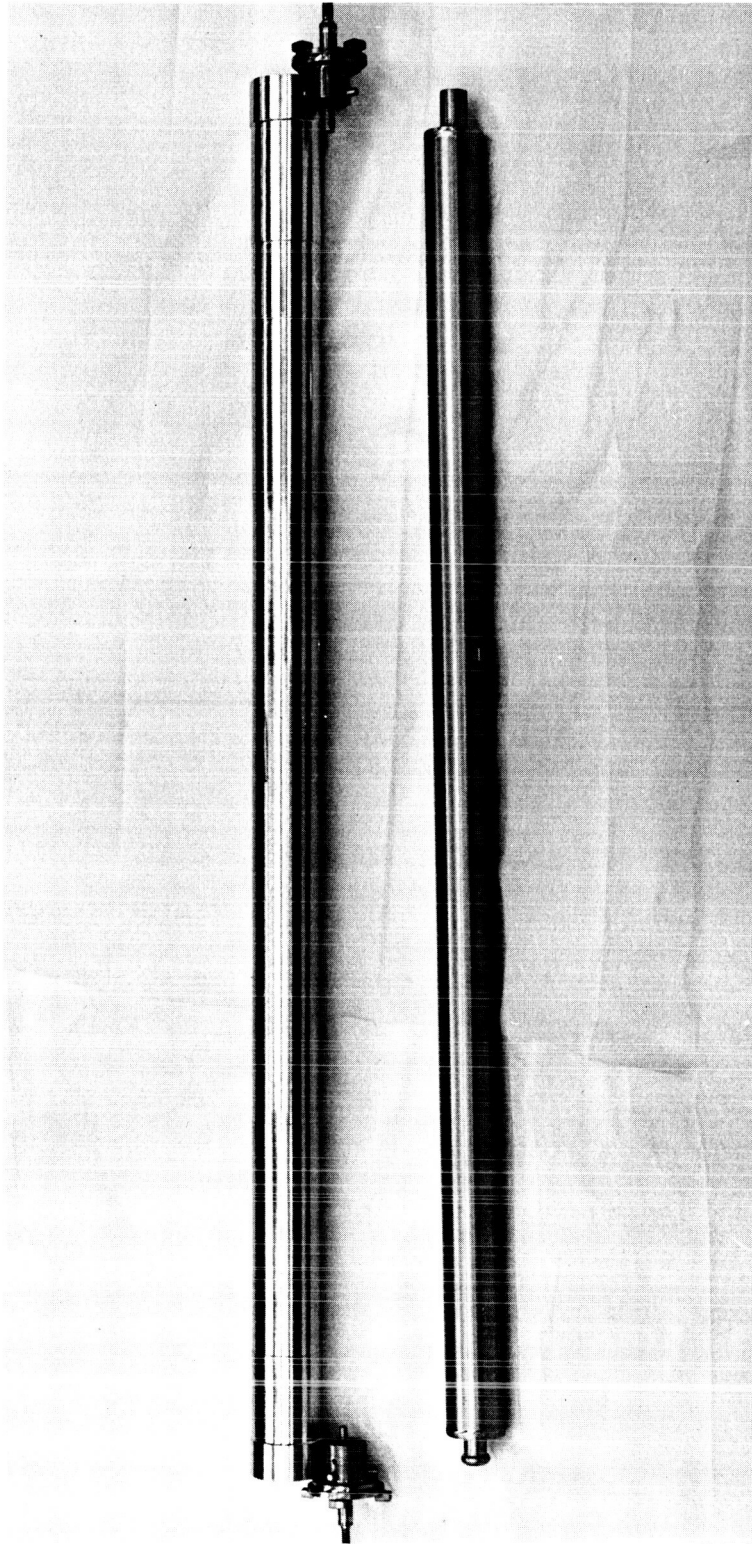


Figure 4. L-Prototype Capsule Ready for Final Assembly

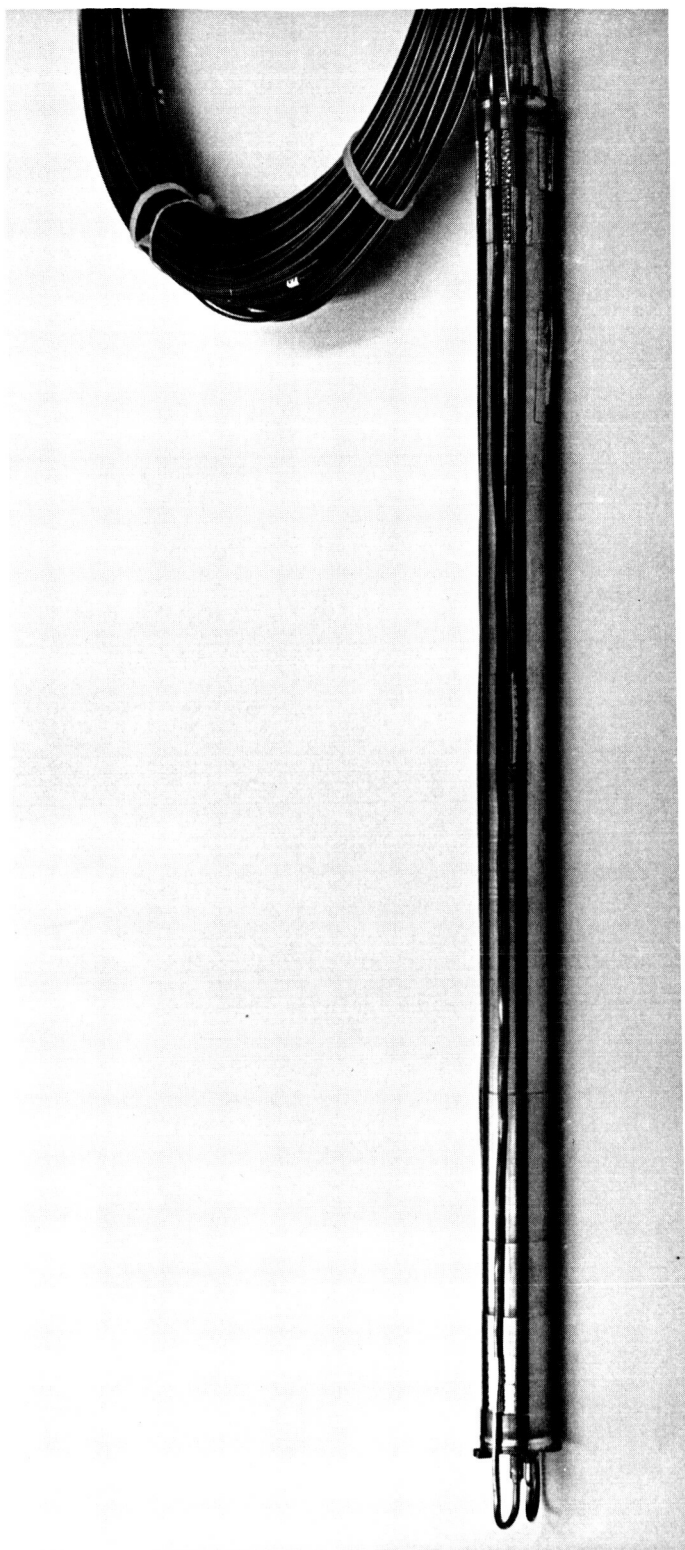


Figure 5. L-Instrumented Capsule Completely Constructed

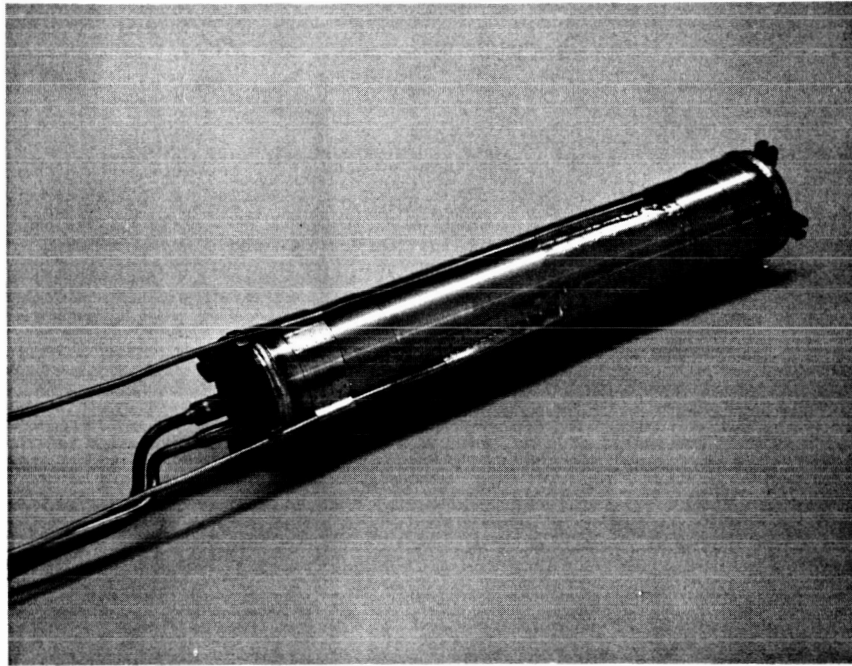


Figure 6. L/3 Capsule Completely Constructed

Capsule materials, machined parts and subassemblies were nondestructively tested throughout the construction process. In addition, selected samples and weldments were destructively examined and tested. Raw material was characterized by specification, heat number, and metallography and was inspected by the visual, dimensional, ultrasonic, and liquid penetrant methods. Machined parts were visually and dimensionally checked, and subassemblies were inspected visually by dye penetrant, helium leak testing, and in some cases by radiography.

Following assembly, the capsules were leak tested, dye penetrant inspected, radiographed, and checked out by heating in a furnace at 533°K (500°F) for thermocouple calibration. The detailed sequence of operations for capsule assembly and inspection are provided in Appendixes B, C, D, and E. These show the exact assembly sequence as well as the thoroughness with which each capsule was documented in this program.

As in previous capsule construction programs, see NASA Contract reports CR-72905 and CR-120188, electron beam welding was the primary assembly process. Low heat input and self-fixturing weld joints result in minimal weld distortion. This feature was essential in achieving the required overall straightness and in achieving close control over concentricity of fuel pin and capsule.

Thermocouple assemblies were also fabricated using electron beam welding for the various joints required. As in previous work, these joints are critical to system performance. Of particular importance is the thermocouple well to thermocouple sheath weld which must withstand handling and flexing during capsule construction and reactor test cycles.

The individual weld joints have a variety of requirements with regard to size, total penetration, and configuration. Figures 7, 8, and 9 illustrate the locations of these welds for each of the capsule designs. Also identified in these figures are the individual weld procedure sheets which detail specific weld parameters. The procedure sheets are presented in Appendix D.

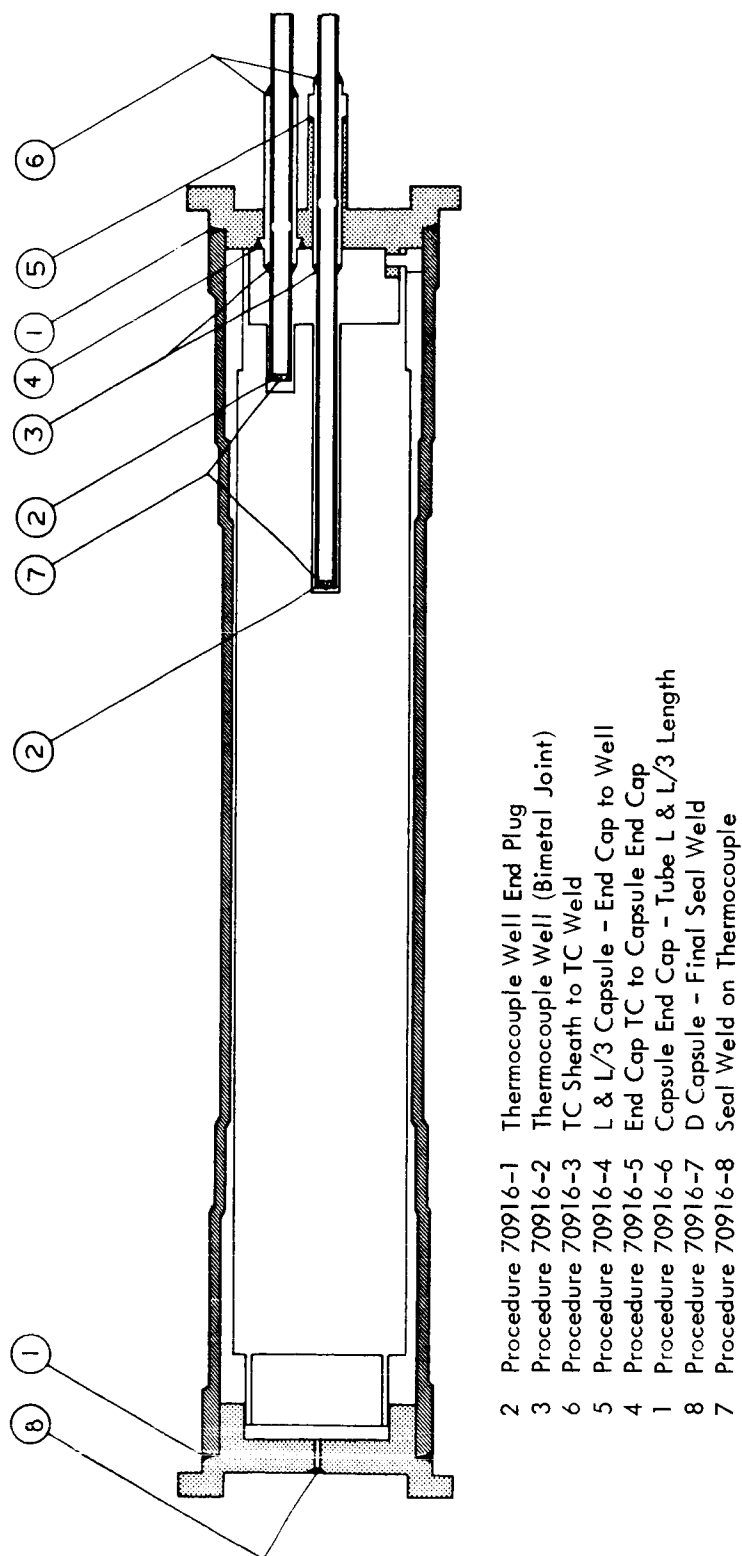
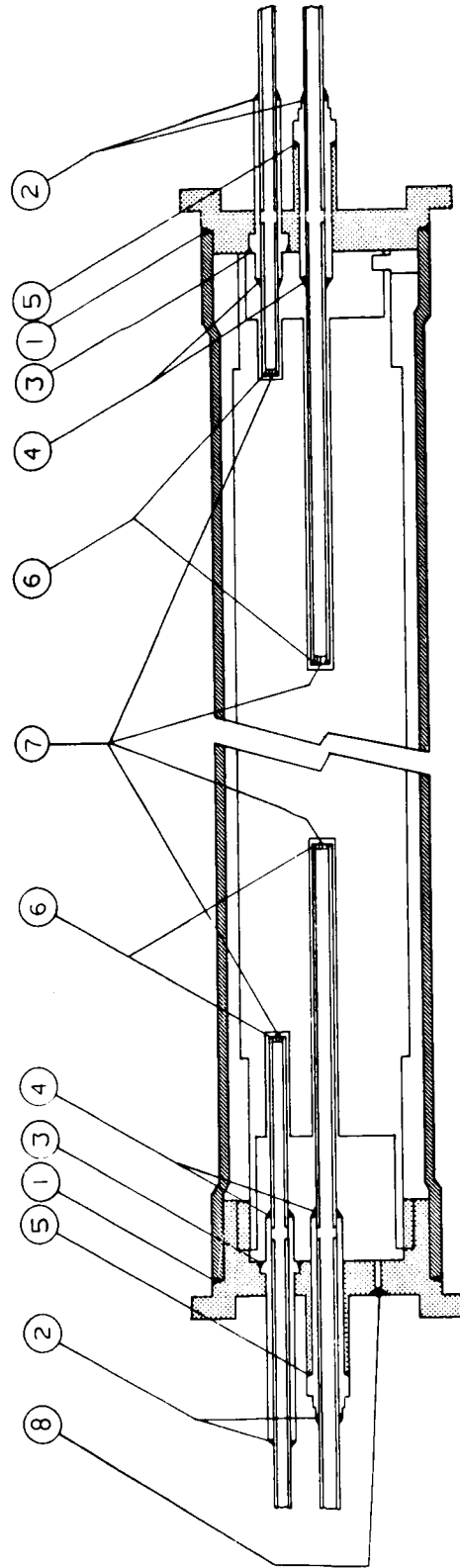
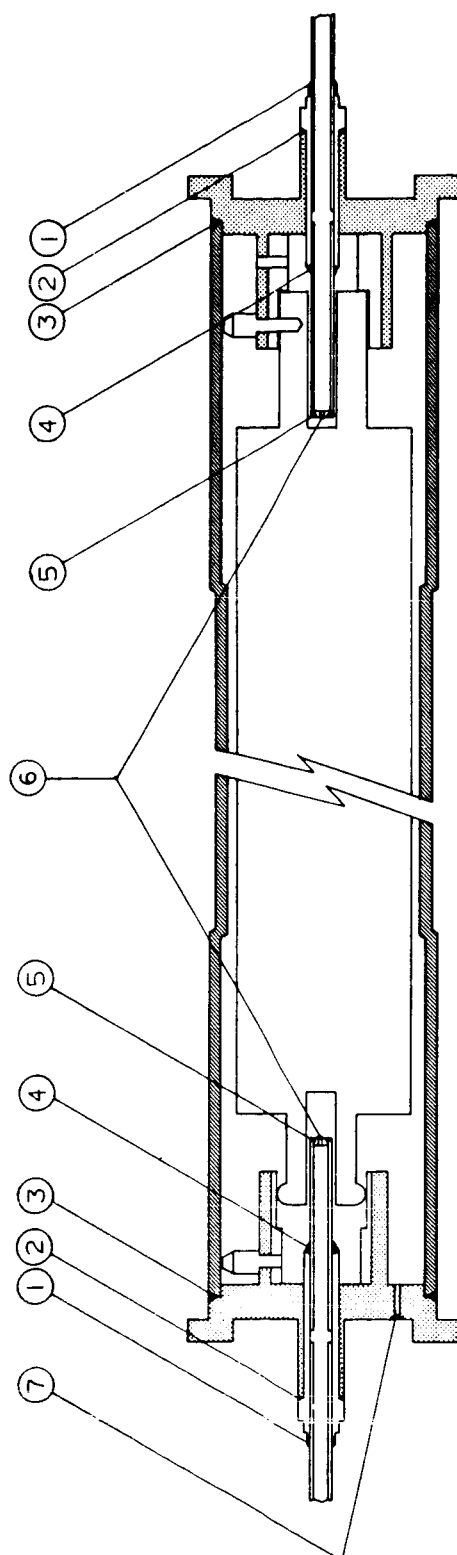


Figure 7. Weld Location Schematic - L/3 Capsule



- 6 Procedure 70916-1 Thermocouple Well End Plug
- 4 Procedure 70916-2 Thermocouple Well (Bimetal Joint)
- 2 Procedure 70916-3 TC Sheath to TC Well
- 5 Procedure 70916-4 L & L/3 Capsule - End Cap Well
- 3 Procedure 70916-5 End Cap TC to Capsule End Cap
- 1 Procedure 70916-6 Capsule End Cap - Tube L & L/3 Length
- 8 Procedure 70916-7 D Capsule - Final Seal Weld
- 7 Procedure 70916-8 Seal Weld on Thermocouple

Figure 8. Weld Location Schematic - L-Instrumented Capsule



- 5 Procedure 70916-1 Thermocouple Well End Plug
- 4 Procedure 70916-2 Thermocouple Well (Bimetal Joint)
- 1 Procedure 70916-3 TC Sheath to TC Well
- 2 Procedure 70916-4 L & L/3 Capsule - End Cap Well
- 3 Procedure 70916-6 Capsule End Cap - Tube L & L/3 Length
- 7 Procedure 70916-7 D Capsule - Final Seal Weld
- 6 Procedure 70916-8 Seal Weld on Thermocouple

Figure 9. Weld Location Schematic - L-Prototype Capsule

In the fabrication of these capsules many previously developed welding procedures were directly applicable. For these cases, in addition to those where new development was required, careful pre- and post-production weld sampling and nondestructive testing were employed to assure weld quality. The specific quality requirements as defined by drawing callout include among others; full penetration, freedom from cracks in welds or adjacent base material, and freedom from porosity, lack of fusion, and overlap.

A weld cracking problem did occur in the early stages of the program which necessitated the development of repair and rewelding procedures. These cracks, associated with material composition, occurred in the weld joining the capsule tube to end caps. Appendix H presents detailed information on the crack location, size, and repair procedure. Ultimately a modified procedure was developed employing a filler material which eliminated the cracking problem.

Localized surface discoloration was observed on and near the end caps of five completed capsule assemblies after receipt at Plum Brook. The surface discoloration was determined to be superficial rust; source unknown. A combination of mechanical and chemical cleaning was used to satisfactorily remove the rust. Details of identification, procedures for removal, and recommendation to prevent reoccurrence in future assemblies are summarized in Appendix J.

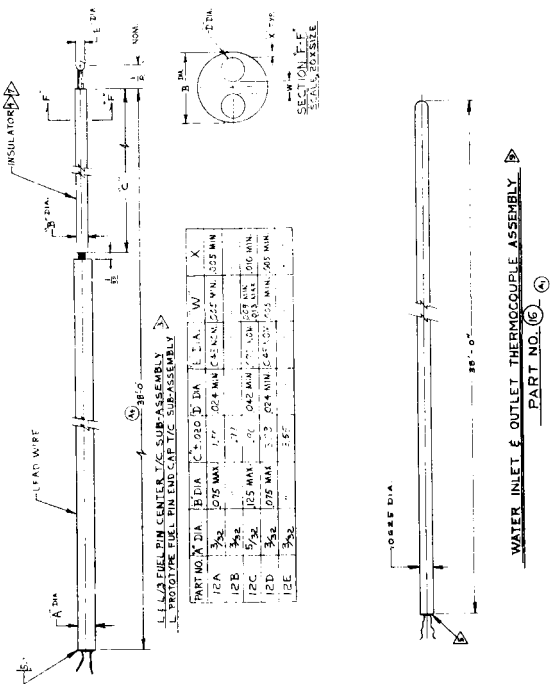
4.0 THERMOCOUPLE ASSEMBLIES

Thermocouple assemblies for capsule instrumentation were constructed to three basic configurations. These were designated as wall, end cap, and fuel center thermocouples. Particulars of each type are described in Table 2 and shown in Figure 10. Step by step construction and inspection procedures are included in Appendix A.

Wall thermocouples were of standard sheathed, grounded junction design and were soldered into slots on the O. D. of the capsule wall. End cap and fuel center thermocouples featured an ungrounded loose hot junction design encapsulated in a tantalum thermocouple well. These were welded into the capsule end cap and extended into wells in the fuel pin.

Elaborate processing was applied to the fuel center and end cap thermocouples in an attempt to produce the most reliable long duration thermocouples possible for in-pile testing. Thermocouple construction began with lead wire in which the purity and cleanliness of components were carefully controlled. Hot zone construction was accomplished in a low humidity controlled clean room with tools and equipment prepared especially to prevent contamination of thermocouple parts. Hot zone ceramic was air and vacuum fired at 1589°K (2400°F) and stored in an inert atmosphere until ready for use. Thermocouple wells were preassembled, leak tested, and maintained in the clean condition until ready for assembly. Exposed chromel/alumel wire was visually and electrically inspected before and after the hot junction was made.

After hot junction fabrication, the open end of the thermocouple was placed in a controlled atmosphere transfer container, Figures 11 and 12, evacuated, and backfilled with high purity helium. The transfer container was removed only in a glove box, thus the open thermocouple was never exposed to uncontrolled ambient air.



18

TABLE 2. CAPSULE THERMOCOUPLE INFORMATION
(All TC Wire of Chromel/Alumel Type)

Thermocouple Configuration (Capsule Position)	Lead Name Specification	Sheath Dia.	Wire Size	No. Wires	Junction Type	Insulation		Thermal Cycle Temperature		Calibration Temperature	
						Hot Zone	Cold Zone	Max.	Min.	Max.	Increment
Wall Thermocouples All Capsules	C-429191-PB	1.58mm (.062")	.25mm (.010")	2	grounded	MgO	MgO	600°K (620°F)	310°K (100°F)	400°K (260°F)	20°K
End Cap L/3 and L-Instrumented L-Prototype (outlet)	C-429192-PB	2.36mm (.093")	.46mm (.016")	4	un- grounded loose	Al ₂ O ₃	Al ₂ O ₃	1100°K (1520°F)	525°K (480°F)	810°K (1000°F)	100°K
End Cap L-Prototype (Inlet)	C-429192-PB	3.96mm (.156")	.92mm (.032")	2	un- grounded loose	Al ₂ O ₃	Al ₂ O ₃	810°K (1000°F)	525°K (480°F)	810°K (1000°F)	100°K
Fuel Center L/3 and L-Instrumented	C-429250-PB	2.36mm (.093")	.45mm (.019")	2	un- grounded loose	Al ₂ O ₃	Al ₂ O ₃	1450°K (2150°F)	525°K (480°F)	1450°K (2150°F)	100°K

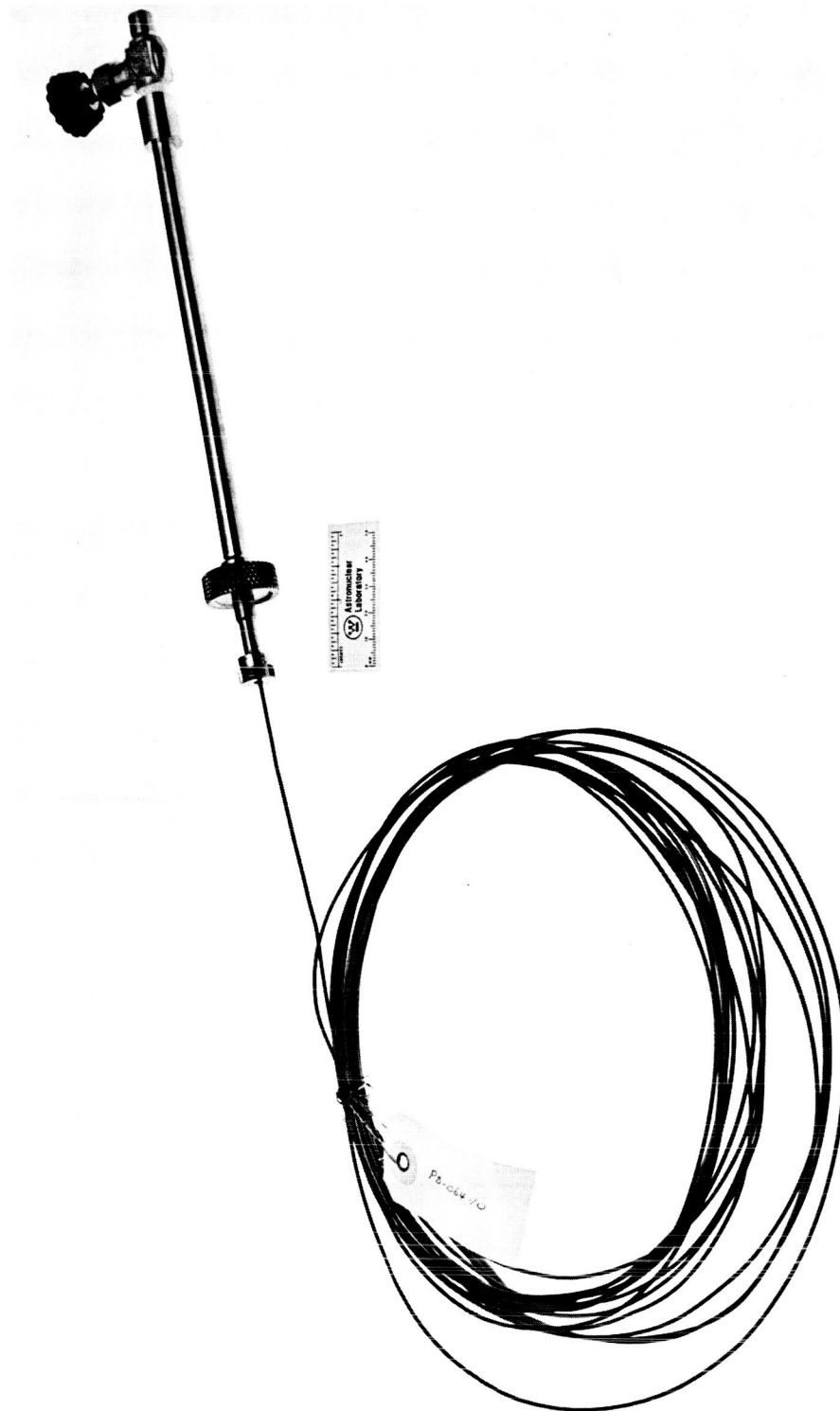


Figure 11. Controlled Atmosphere Thermocouple Transfer Container with Thermocouple

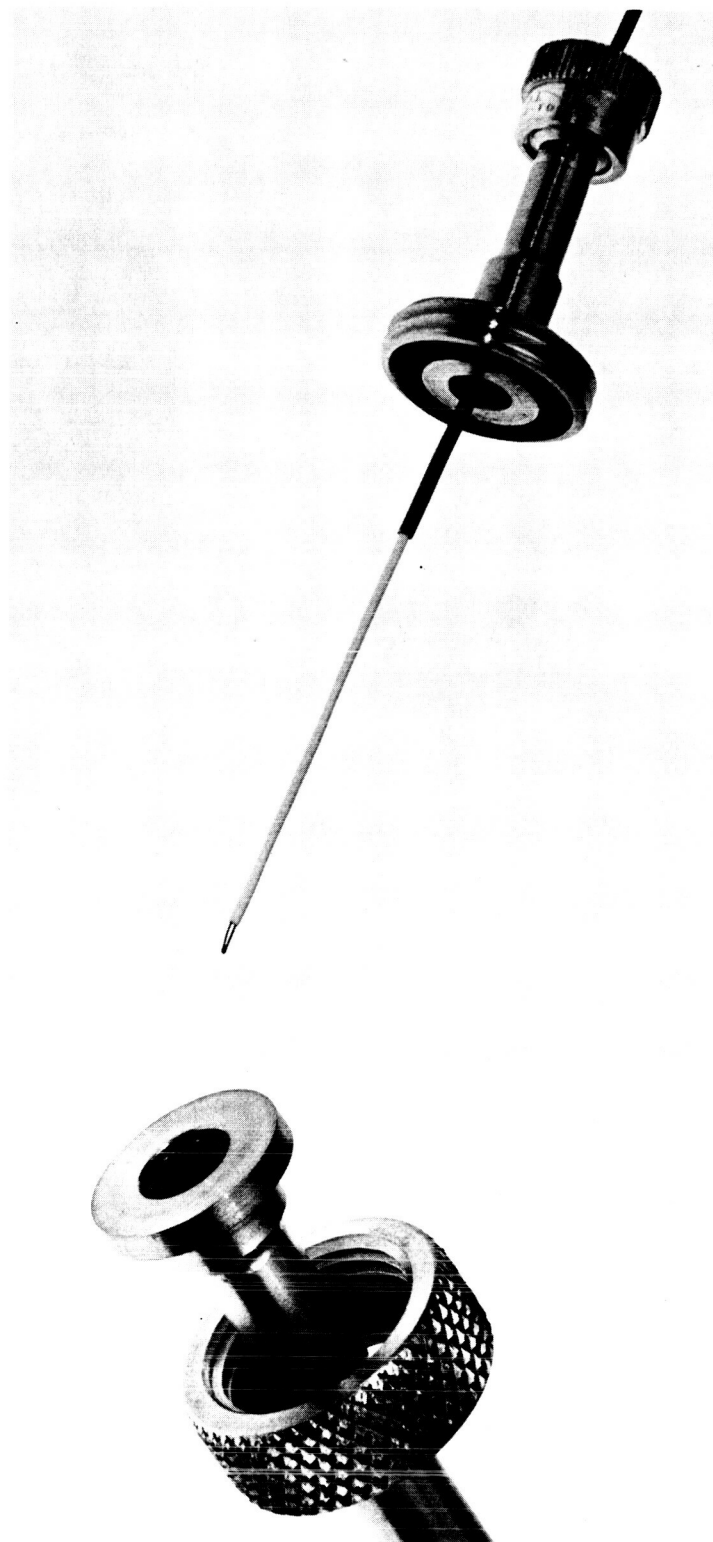


Figure 12. Controlled Atmosphere Thermocouple Transfer Container
Separated at "O" Ring Seal

A minimum of 2 feet of the hot end of each thermocouple was baked out at 1030°K (1400°F) for 4 hours in vacuum .00665 Pa (5×10^{-5} Torr) or better, and each thermocouple well was baked out at 535°K (500°F) for one hour. They were cooled to ambient temperature, the chamber backfilled with high purity helium, and the well was mated to the thermocouple. This was accomplished in the thermocouple bakeout and assembly chamber, Figure 13. The thermocouple assembly hot end was again sealed in the transfer container, and the assembly was moved to the electron beam welding and assembly chamber where the well to sheath EB weld was made. The final fabrication step was the sealing of the thermocouple well in high purity monitored helium by GTA spot welding.

Post-assembly inspection included visual examination, dye penetrant tests, thermal cycle tests, calibration, x-ray, helium leak check after pressurizing the entire unit at 1.55 MPa (225 psi), helium, and electrical tests. At an applied voltage of 500 volts, breakdown was observed of both two wire and four wire thermocouples. A 100 volt breakdown test was then substituted as part of the acceptance criteria for the thermocouples. A "Thermocouple Assembly Fabrication Procedure" was completed for each thermocouple built.

As part of the thermal cycle and calibration test, a typical thermocouple was destructively examined. Metallographic inspection of the tantalum tube revealed a layer of contamination apparently originating from the interior of the well. As a result, a study was performed to isolate the type and source of the contamination. The results of this study are presented in Appendix I.

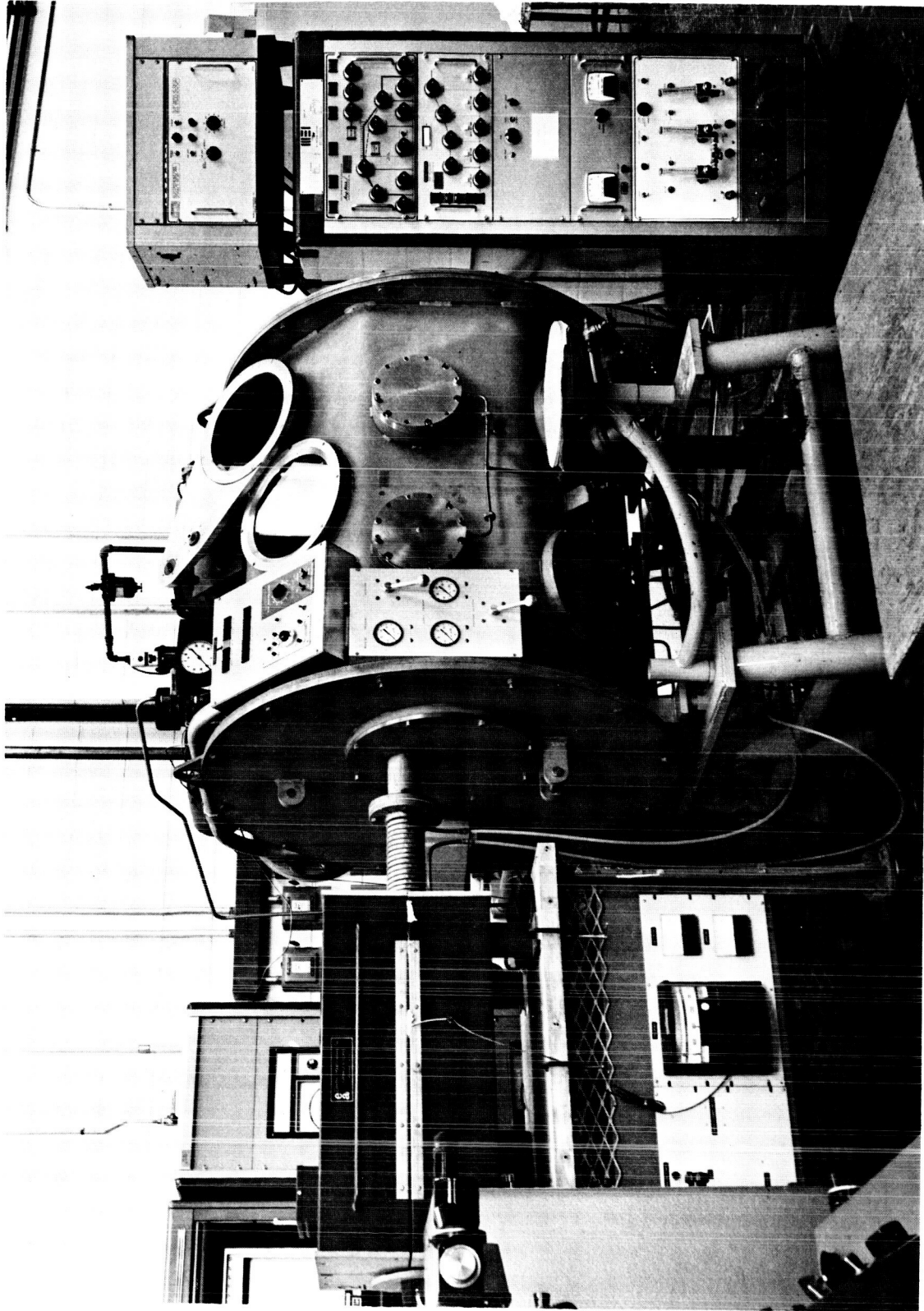


Figure 13. Thermocouple Bake Out and Assembly Chamber

APPENDIX A
Thermocouple Assembly Fabrication Procedures

1.0 THERMOCOUPLE ASSEMBLY FABRICATION PROCEDURES

Thermocouple Mfg. No. _____
Sheath Dia. (Nom.) _____
No. of Wires _____
Wire Dia. (Nom.) _____
Location _____

1.1 Receiving Inspection

- ___ 1.1.1 Visually examine (at 5X) entire sheath for fissures, pits, cracks, or other flows. Mark suspected areas if any and record location on a sketch.
- ___ 1.1.2 Zyglo test any suspected areas in accordance with WANL Process Spec. 294564-6 Class 00. Results _____
- ___ 1.1.3 Measure length of thermocouple to the nearest 1/8".
Length _____ (38 ft. minimum length)
- ___ 1.1.4 Measure diameter of thermocouple at (3) locations along length.

	Min.	Max.
Dia. 1	_____	_____
Dia. 2	_____	_____
Dia. 3	_____	_____

- ___ 1.1.5 Thermocouple accepted _____ rejected _____
(per NASA Spec. C-429250-PB Fuel Center Thermocouples
C-429192-PB End Cap Thermocouples
C-429191-PB Wall Thermocouples)

Comments: _____

- ___ 1.1.6 Clean as follows:
- ___ 1.1.6.1 Remove all liquid penetrant with the cleaner specified by the manufacturer of the penetrant.
- 1.1.6.2 Wipe thermocouple sheath with a lint free cloth or Kim Wipe dampened with M-6 (oxylene) then with a dry cloth or Kim Wipe.

- 1.1.6.3 Wrap thermocouple sheath onto an assembly roll or into a coil 12.0" dia.
- 1.2 Pre-Assembly
 - 1.2.1 Alumina insulator preparation
 - 1.2.1.1 Prepare a baking furnace as indicated in Figure A-1.
 - 1.2.1.2 Load empty high purity alumina boats into mullite tube and bake out at $1480 \pm 20^{\circ}\text{K}$ (2200°F) for (4) hours (minimum) with mullite tube open to ambient air.
 - 1.2.1.3 Immediately after air bake out, bake out mullite tube and alumina boats in vacuum of 5×10^{-3} torr or better for 24 hours at $1480 \pm 20^{\circ}\text{K}$. Cool to room temperature and backfill with clean dry helium. Maintain a positive helium pressure until ready for next step.
 - 1.2.1.4 Load thermocouple insulators into alumina boats (baked out above) and repeat bakeout procedure in 1.2.1.2 and 1.2.1.3.
 - 1.2.1.5 Prepare a thermocouple insulator holding chamber as indicated in Figure A-2. Clean chamber, lines and fittings in accordance with cleaning procedure Section 6.0.
 - 1.2.1.6 Immediately after thermocouple insulator bakeout in Section 1.2.1.3 transfer alumina boats containing thermocouple insulators to holding chamber. Evacuate holding chamber to less than 1×10^{-1} torr and backfill with high purity helium to 1-5 psig. Maintain holding chamber at this pressure at all times except when removing a thermocouple insulator. Insulators shall be handled only with stainless-steel tweezers that have been ultrasonically cleaned in fresh C.P. ethyl alcohol and have not been subsequently contaminated. Insulators shall remain in the dry helium atmosphere until the moment of assembly.
 - 1.2.2 Assembly clean room and tool preparation
 - 1.2.2.1 An atmosphere controlled clean room that meets or exceeds the standard specified in WANL Process Specification 294579 Revision No. 2 designation 294579-3 (except as noted below) shall be established and maintained while working on thermocouples open to ambient air. In addition relative humidity shall be controlled at or below 24% at all times.

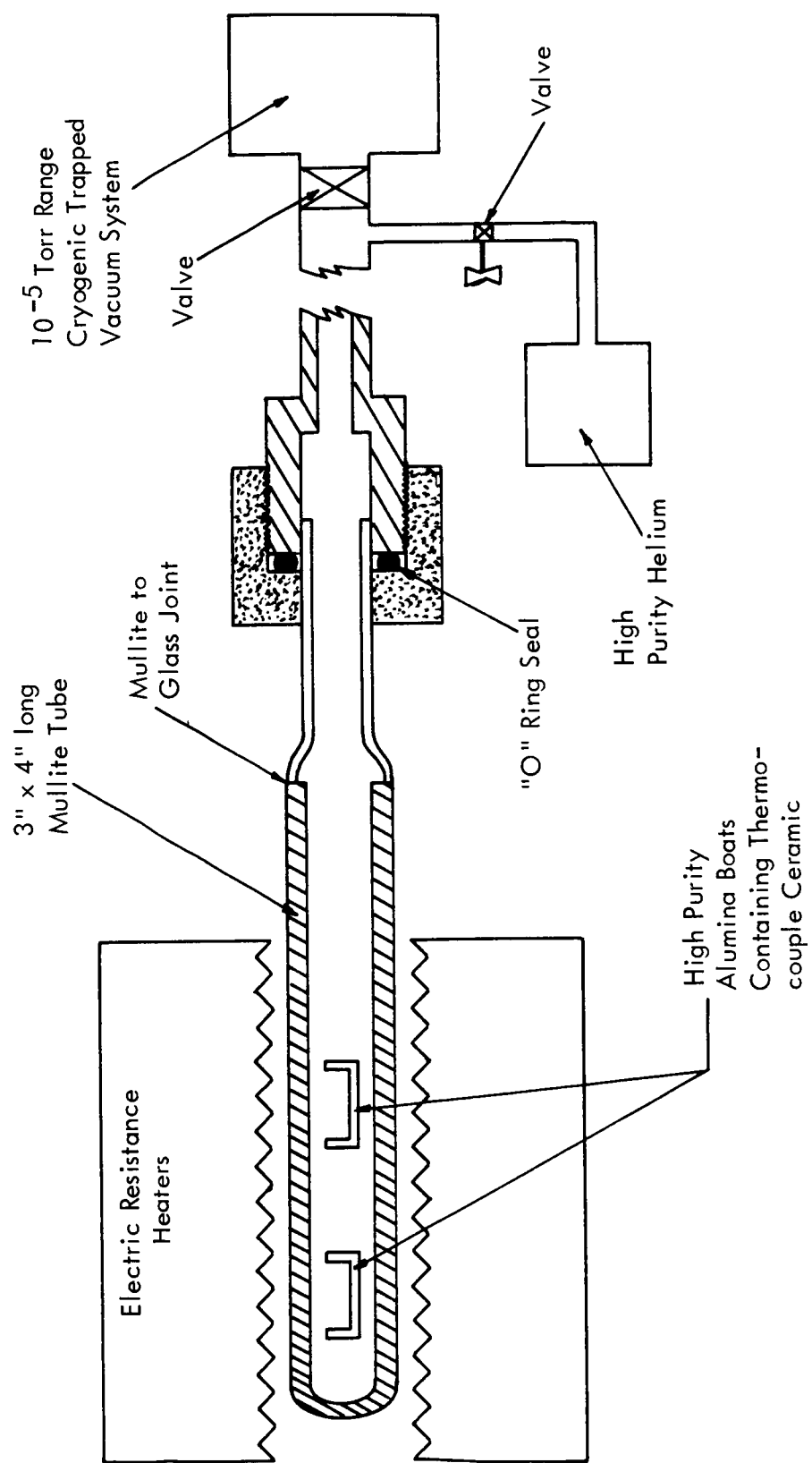


Figure A-1. Thermocouple Ceramic Baking Furnace

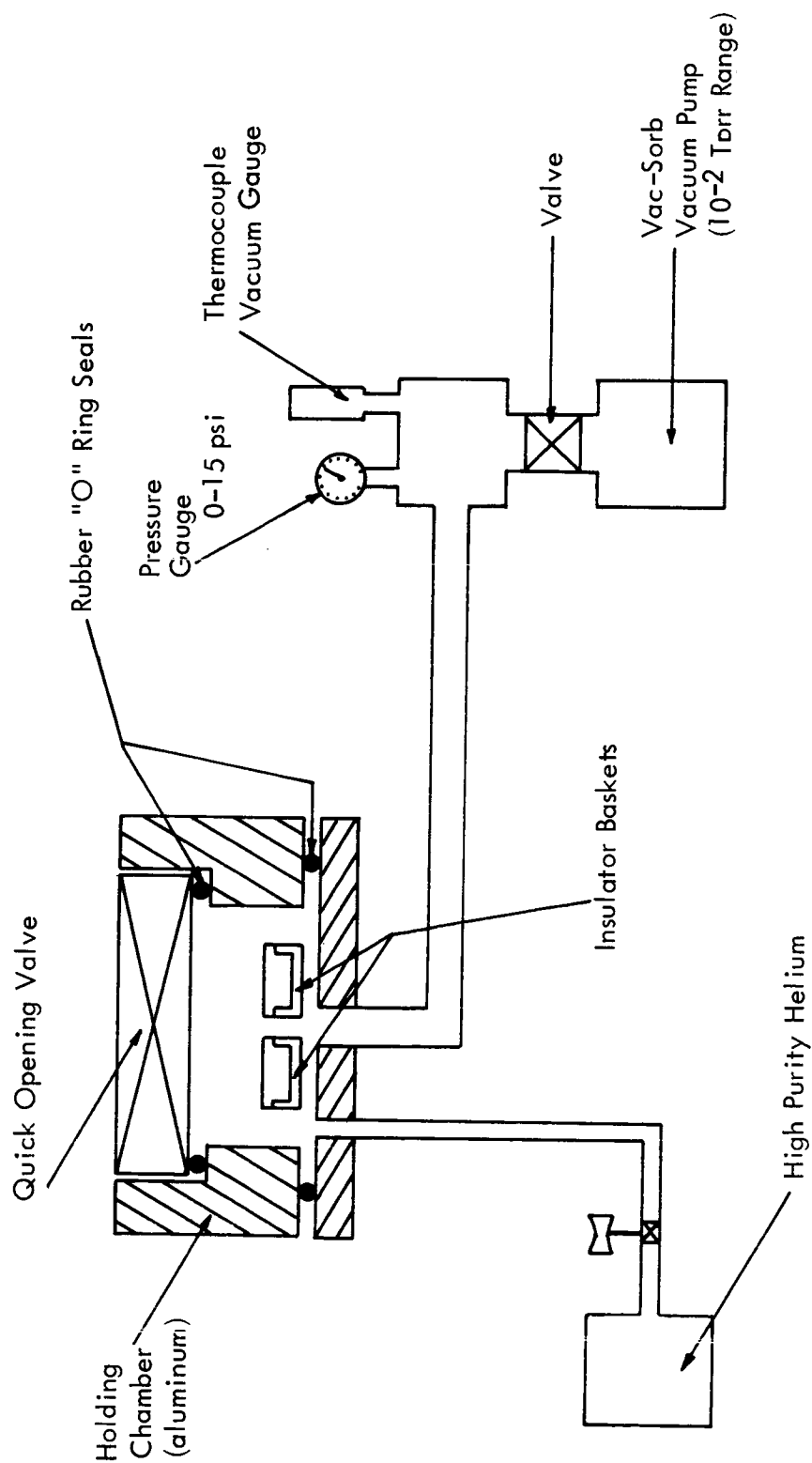


Figure A-2. Thermocouple Insulator Holding Chamber

Exceptions to WANL Process Specification 294579-3:

2.1 delete integrated lavatory facilities

3.3.1 delete

3.3.2 delete

3.3.3 delete

4. delete - regular employees shall keep street clothes in locker room and shall wear the following provided clothing: Complete underwear change, socks, coveralls, head cover, shoes and surgical rubber gloves or the equivalent.

delete - "Visitors" and substitute "All Personnel" in sentence that specifies clothing.

_____ 1.2.2.2 The work area table top shall be of clean stainless steel or lined or covered with dust-free teflon. Gloves, table tops, and trays shall have received prior cleaning in accordance with cleaning procedures Section 6.0 and thereafter shall not be touched with the fingers.

_____ 1.2.2.3 The sheath stripping tool and ceramic scraping tool used to perform the following operations shall be completely new tools, and except for the stripping tool cutting edge, shall be fabricated of stainless steel.

Tools shall be visually inspected at 10X to confirm that no foreign particles are imbedded in the cutting or scraping surface.

Tools shall be thoroughly cleaned and degreased by ultrasonically cleaning in fresh C.P. ethyl alcohol, or in a vapor degreaser. Tools shall be handled only with lint-free, non-porous gloves which have themselves received prior cleaning with fresh C.P. ethyl alcohol. At the completion of any washing operation, tools shall be dried in a jet of dry, clean air or argon at a temperature of $200^{\circ}\text{C} \pm 50^{\circ}\text{C}$. Commercial grade bottled gases satisfy the dry, clean requirement in this specification. Plant (commercial) air systems do not.

1.3 Fuel Center and End Cap Thermocouple Hot Junction Construction

(Note: Any time thermocouple has been opened to ambient air and is not being worked on, the open end shall be covered by a controlled atmosphere thermocouple transfer container under vacuum or filled with clean, dry helium).

1.3.1 Visual inspection of TC wire

1.3.1.1 Strip sheath back from hot zone end of sheathed thermocouple lead wire for distances specified in NASA Dwg. PF-10664. (Deburr end of sheath).

1.3.1.2 Visually inspect the exposed wires at not less than 10X diametral magnification. The presence of a nick or inclusion whose major lateral dimension exceeds ten percent of the wire diameter shall be sufficient cause for rejection of that segment of wire. Cut off the defective end and repeat the stripping and inspection steps on the newly exposed thermocouple wires. Repeat as required to obtain defect-free length of stripped thermocouple wire.

1.3.1.3 Visually inspect the exposed wires at not less than 25X diametral magnification to detect the presence of scratches or drawmarks. The presence of such a defect whose maximum lateral width exceeds ten percent of the wire diameter shall be sufficient cause for rejection of that segment of wire. Cut off the defective end and repeat the stripping and inspection steps on the newly exposed thermocouple wires. Repeat as required to obtain a defect-free length of stripped thermocouple wire.

Measure to the nearest 1/8" the total length of thermocouple wire (double) removed while preparing hot junction. Length removed _____.

1.3.2 Electrical resistance measurements

1.3.2.1 Make the following resistance measurements at no less than 50 vdc at room temperature with a freed megger model 1020C or equivalent. Instrument description if different from above _____.

- a) Positive wire to sheath _____ (ohms)
- b) Negative wire to sheath _____ (ohms)
- c) Wire to wire _____ (ohms)

All of the above measurements must be equal to or greater than 1×10^9 ohms.

Thermocouple accepted _____ rejected _____

1.3.2.2 Make the following resistance measurements:

- a) Positive wire hot junction end to positive wire cold end _____ (ohms)
- b) Negative wire hot junction end to negative wire cold end _____ (ohms)

1.3.3 Making hot junction

1.3.3.1 Assemble hard fired alumina insulators onto thermocouple wires in accordance with NASA Dwg. PF 10664. Insulators shall consist of a single length piece of ceramic between the junction and the stainless steel sheath section of the thermocouple. All materials are to be handled with clean lint-free gloves and clean stainless steel handling tools on a clean table top. Cleanliness of gloves, tools, and table top shall be achieved and maintained through the techniques itemized in Procedure 6.

The total time elapsing between the first withdrawal of insulators from the desiccator (at the commencement of the assembly operation) until the installation of the thermocouple subassembly in the controlled atmosphere thermocouple transfer container shall not exceed four hours.

- 1.3.3.2 a) Clamp correct length of thermocouple hot end in a copper heat sink with .010" protruding.
- b) Position electrode of "Dynatech Corp." Model 216 Wg Welder with extension welding head or equivalent .060" above thermocouple. Note: ground lead is connected to heat sink.
- c) Set welding control:
 - Weld time - minimum
 - Weld current - minimum
 - Pre-purge - 50%
 - Post-purge - 50% use ultrapure argon
- d) Make weld
- e) Inspect weld bead at 25X for cracks, pits, lack of fusion or necking down of the wire and remove junction if any of the above are noted. Weld bead diameter shall not exceed 2.5 diameters of one wire diameter.
- f) Test fit ceramic cup over TC junction. It must fit loosely.

1.3.3.3 Measure circuit resistance to nearest .01 ohm _____. Measure ambient temperature in vicinity of thermocouple lead when resistance measurement is made. (Note entire thermocouple is to be at the same ambient temperature) _____ °F.

____ 1.3.3.4 Thermocouple accepted _____ rejected _____
based on a comparison of the resistance per unit length
corrected for temperature deviation.

Note: Resistance per unit length shall be determined and recorded with an inaccuracy of less than 0.1 percent. Any assembly shall be rejected in which the resistance per unit length differs from the mean of all wires by more than three times the average deviation from the mean.

- a) Thermocouple resistance _____ ohms per foot.
- b) Mean average of all wires in the same batch.
Resistance _____ ohms per foot.
- c) Three times average deviation from mean _____ ohms.
- d) Thermocouple deviation from mean _____ ohms.

____ 1.3.3.5 Immediately after assembly and inspection of hot junction, insert hot junction end into a controlled atmosphere thermocouple transfer container, evacuate to less than 100 millitorr and backfill to 5 psig with clean dry helium.

____ 1.3.3.6 Transfer thermocouple subassembly into the inert atmosphere thermocouple bakeout assembly chamber as soon as practical.

Note: Thermocouples are to be stored in the clean room until a working batch is ready for further processing then they are to be moved to the thermocouple bakeout-assembly chamber. No other storage or work location is to be used.

1.4 Thermocouple Well Assembly

____ 1.4.1 Clean thermocouple well parts in accordance with cleaning procedure No. 5.

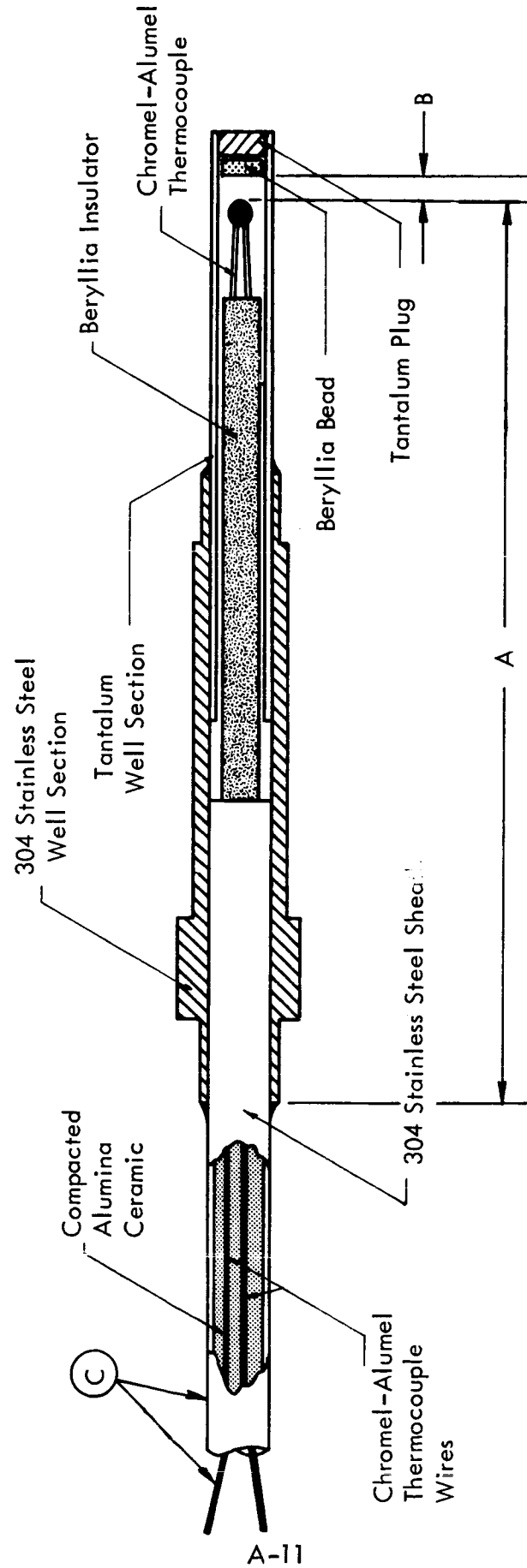
____ 1.4.2 Assemble and weld together parts in accordance with Dwg. PF-10652 and welding procedures defined in Procedure 4.

- a) Insert Ta plug into end of Ta tube and EB weld.
- b) Mate Ta tube with stainless steel section of TC well and adjust length as indicated on drawing.
- c) Install Ta ring over bimetal joint and EB weld.

____ 1.4.3 Mass spec helium leak check TC well assembly by evacuating TC well from open end and plugging no. 69 hole in Ta plug with a small rubber stopper. Use care not to cover Ta plug to Ta tube weld so this weld can be leak tested at the same time as bimetal joint.

Leak detector calibration _____ std cc/sec
TC well leak rate _____ std cc/sec

- 1.4.4 Store completed thermocouple wells in clean glass containers until ready for use.
- 1.5 Thermocouple Hot End Bakeout and Assembly (Fuel Center and End Cap)
- 1.5.1 Bakeout empty thermocouple bakeout furnace at 1030°K (1400°F) for 4 hours at 5×10^{-5} torr or better and do not expose to air before baking out TC's. If at any time after initial bakeout the furnace is exposed to ambient air for 30 minutes or longer, rebake furnace before processing thermocouples.
- 1.5.2 Remove transfer container from hot end of thermocouple inside the helium filled bakeout glove box.
- 1.5.3 Place a clean, dry, 99.7% purity alumina tube over the hot junction end of the thermocouple subassembly, to prevent cross contamination of the hot junction ceramic during the high temperature bakeout of the thermocouple.
- 1.5.4 Bakeout a minimum two feet length of the hot junction end of thermocouple at 1030°K ($1400^{\circ}\text{F} \pm 50$) for 4 hours in vacuum 5×10^{-5} torr or better, then cool to room temperature and backfill with clean dry helium. (Note bakeout the thermocouple cup at the same conditions as the thermocouple hot end with the cups protected by a high purity (99.7%) alumina boat).
- 1.5.5 Inspect thermocouple hot zone ceramic for discoloration. (Note if any discoloration is noted do not assemble thermocouple into TC well unless specified by the NASA Project Manager).
- 1.5.6 Bakeout thermocouple well for (1) hour at a maximum temperature of 535°K (500°F) in vacuum of 5×10^{-5} torr or better. Cool to room temperature and do not expose to air before thermocouple assembly is made.
- 1.5.7 Assemble thermocouple into thermocouple well in accordance with NASA Dwg. PF-10664. (Assembly to be accomplished in a dry helium atmosphere with continuous analysis for O_2 and H_2O . If either exceeds 5 ppm (V) pump out chamber and backfill with clean gas).
- 1.5.7.1 Insertion depth _____ refer to Figure A-3. Determine by measuring depth of thermocouple well with cup installed and subtracting 1.59 mm (1/16").
- 1.5.7.2 Clearance between thermocouple and ceramic cup _____
Min. .79 mm (1/32) Max. 2.38 mm (3/32)
- 1.5.7.3 TC resistance wire to sheath _____. Checked with VOM on 100K scale - must indicate near infinite.



- A - Insertion Depth _____
- B - Thermocouple End Clearance _____
- C - Thermocouple Insulation Resistance _____

Figure A-3. Thermocouple Hot Zone Construction

- _____ 1.5.7.4 Install transfer container over hot junction and transfer thermocouple to Sciaky EB weld chamber.
- _____ 1.5.8 EB weld TC well to TC sheath in accordance with Procedure 4, Welding.
- _____ 1.5.9 TIG weld closure hole in Ta plug of thermocouple well in accordance with Procedure 4, Welding. Hole closure is to be accomplished in an ultra pure helium atmosphere with O_2 and H_2O monitored. Maximum allowable limit is 5 ppm (V) for either O_2 or H_2O .
- _____ 1.5.9.1 Visually inspect weld _____.
- _____ 1.5.9.2 TC resistance wire to sheath _____. Checked with VOM on 100K scale - must indicate near infinite.
- _____ 1.5.9.3 Mass spec leak check TC in an evacuated chamber connected to leak detector. Leak detector calibration (minimum detectable leak) _____. Leak rate _____ acceptable leak rate is $< 1 \times 10^{-8}$ cc/sec.

1.6 Wall Thermocouple Construction

Note: Any operation that requires thermocouple to be open to ambient air shall be performed in the humidity controlled clean room.

- _____ 1.6.1 Strip sheath back approximately 25 mm (1") from cold end of thermocouple and seal sheath end with epoxy resin. (Hysol No. 0151 clear or 1C white).
- _____ 1.6.2 Inspect weld bead at hot junction at 25X for cracks, pits, or lack of fusion and if any anomaly is noted report finding to Project Manager for disposition.
- _____ 1.6.3 Measure circuit resistance to nearest .01 ohm, _____ ohms, and ambient temperature in the vicinity of thermocouple lead at the time resistance measurement is made, _____ °F.
- _____ 1.6.4 Thermocouple accepted _____ rejected _____ based on a comparison of the resistance per unit length (corrected for temperature deviation).
- a) Thermocouple resistance _____ ohms/ft
- b) Mean average resistance for all wires of same batch _____ ohms/ft
- c) Three times average deviation from mean _____ ohms
- d) Thermocouple deviation from mean _____ ohms

1.7 Thermal Cycling (End Cap and Capsule Wall Thermocouples)

The thermocouple assemblies shall be thermally cycled four times over the temperature range specified as follows:

<u>Thermocouple Type</u>	<u>Maximum Temperature</u>	<u>Minimum Temperature</u>
End cap thermocouples L/3, L instrumented, and L prototype capsules	$1100 \pm 25^{\circ}\text{K}$ (1520°F)	$525 \pm 25^{\circ}\text{K}$ (480°F)
Capsule wall thermocouples	$600 \pm 10^{\circ}\text{K}$ (620°F)	$310 \pm 10^{\circ}\text{K}$ (100°F)

The temperature of the Ta-SS e.b. weld in part no. 4 of PF-10652 shall not exceed 810°K (1000°F) during the thermal cycling tests. One spare end cap thermocouple assembly approximately two feet long, shall be sectioned and examined for possible degradation caused by thermal cycling.

Resistance measurements shall be performed on the thermocouple assemblies prior to the start of the thermal cycling tests while the thermocouple assembly is at ambient temperature.

- 1.7.1 Clean thermal cycle rig in accordance with Cleaning Procedure, No. 6. Bakeout the thermal cycle-calibration rig for one hour after cleaning at the pressure and temperature requirements for the thermocouples to be tested prior to the installation of the thermocouples. Maintain rig under vacuum at all times except when being worked on. If rig is exposed to air for more than 1/2 hour at any time after bakeout, repeat bakeout before testing thermocouples.
- 1.7.2 Install six thermocouples in thermal cycle rig and connect output of thermocouple in position no. 1 to read out instrument.
- 1.7.3 Evacuate rig to 5×10^{-6} torr. Keep cold trap filled with LN_2 .
- 1.7.4 Slowly apply heat with induction heater to 525°K (480°F) while maintaining vacuum in the 10^{-5} torr or better range.
- 1.7.5 Rapidly increase temperature to the maximum value. Hold for 1 min. then cool to the minimum value for the type of thermocouple as indicated in paragraph 7.0. Note: Use optical pyrometer to check susceptor temperature and if indication is not within 25°K (75°F) of thermocouple reading, read all of the thermocouples and control the temperature to the average temperature.

- 1.7.6 Repeat paragraph 1.7.5 3 more times then cool to room temperature before removing thermocouples from vacuum furnace. On the fourth heatup when thermocouple is at maximum temperature record the wire to wire and wire to sheath resistance. (Wire to sheath resistance to be 10K ohm or better).

1.8 Calibration - End Cap and Wall Thermocouples

— 1.8.1 End cap thermocouples

- 1.8.1.1 Wrap thermocouple well in clean tantalum foil

- 1.8.1.2 Wrap standard calibrated thermocouple (traceable to the National Bureau of Standards with error limits within $\pm 3/4\%$ for the specified calibration range) with clean tantalum foil over the heated length.

- 1.8.1.3 Bundle thermocouples to be calibrated together with standard thermocouple and insert 1 ft into the hot zone of the vacuum pumped calibration furnace.

- 1.8.1.4 Evacuate furnace to 5×10^{-5} torr or better and heat thermocouples until standard thermocouple indicates $510^{\circ}\text{K} \pm 25$ (458°F). Allow temperature to stabilize then record output of each thermocouple.

- 1.8.1.5 Increase furnace temperature in steps of 100°K to a maximum temperature of 810°K (998°F). Allow temperature to stabilize at each step and record output of each thermocouple. Maintain vacuum in the 10^{-5} torr range or better throughout elevated temperature operation.

— 1.8.2 Wall thermocouples

- 1.8.2.1 Calibrate wall TC's at $400 \pm 10^{\circ}\text{K}$ (260°F) and 3 lower temperature levels 20°K apart.

- 1.8.3 Plot deviation of each thermocouple from standard temperature and refer deviations greater than $3/4\%$ to NASA Project Manager for disposition.

1.9 Thermal Cycle - Calibration (Fuel Center Thermocouples)

(Note: Clean and bakeout thermal cycle-calibration rig in accordance with 1.7.1).

- 1.9.1 Install (6) fuel center thermocouples into the thermocycle/calibration rig pre-cleaned as specified in Procedure 6, Cleaning.

- 1.9.2 Connect output of each thermocouple to a suitable precision readout instrument.
- 1.9.3 Evacuate rig to 5×10^{-5} torr or better. (Keep cold trap filled with LN_2). Note: Maintain pressure in the 10^{-5} torr range or better at all times that temperature is above 150°F .
- 1.9.4 Slowly heat susceptor to $525 \pm 25^\circ\text{K}$ (480°F) and hold until pressure is below 5×10^{-5} torr. Note: Ta-SS bimetal joint must be positioned so that it will not exceed 810°K (1000°F) when thermocouple junction is at its highest temperature.
- 1.9.5 Rapidly heat susceptor (avs. optical pyrometer reading) to $1450 \pm 25^\circ\text{K}$ (2150°F). Allow temperature to stabilize then record output of each thermocouple and the high and low susceptor temperature.
- 1.9.6 Reduce temperature to 1150°K (1605°F) in steps of 100°K allow temperature to stabilize at each temperature level and record temperatures as in paragraph 9.5.
- 1.9.7 Cool to $525 \pm 25^\circ\text{K}$ (480°F) as rapidly as possible and allow temperature to stabilize.
- 1.9.8 Repeat paragraph 1.9.5 and 1.9.6 three more times for a total of 4 thermal cycles and 4 calibration points on each thermocouple at each temperature level. On fourth heatup when TC is at maximum temperature record wire to wire and wire to sheath resistance. Note: if thermocouple temperature deviation is more than 3/4% cool susceptor to ambient temperature after each cycle and switch thermocouples to a different position in the susceptor.
- 1.9.10 Plot deviation of each thermocouple from standard temperature and refer deviations greater than 3/4% to NASA Project Manager for disposition.

1.10 Thermocouple Inspection (All Thermocouples)

- 1.10.1 Record loop resistance of all thermocouples to nearest .01 ohm. Record wire to sheath resistance of fuel center and end cap thermocouples. Reject any assembly in which the resistance per unit length differs from the mean of all wires by more than three times the average deviation from the mean.
- 1.10.2 Helium Leak Test (fuel center and end cap thermocouple assemblies only)

After completion of the resistance measurements and calibrations, the thermocouple assemblies shall be subjected to an external pressure of 225 psig of helium for 1/2 hour. This shall be accomplished by placing entire thermocouple in a pressurizing chamber and pressurizing with helium to 225 psig for 1/2 hour. During the pressurization, cold end of thermocouples shall be sealed with a stainless steel tube and compression fitting.

Immediately after releasing pressure from pressurizing chamber, remove cold end seal fitting and submerge entire thermocouple in a C.P. alcohol bath for (1) minute. Carefully check entire thermocouple for bubble release and if noted reject thermocouple. Bubble check accepted _____ rejected _____. Transfer thermocouple to a leak check chamber connected to a calibrated mass spectrometer leak detector within 15 minutes after pressure is released. Check for leaks by evacuating chamber and testing for helium. Leak detector calibration (minimum detectable leak) _____ std cc/sec. Thermocouple leak rate _____ std cc/sec.

The leak rate shall be less than 1×10^{-8} cc/sec from the entire assembly. If excessive leakage is measured, the assembly shall be either set aside or repaired. Perform a leak detector standard calibration before each test. Before and after testing the background leak rate shall be measured and the thermocouple assembly leak rate calculated and recorded. After completion of the helium leak test, perform the resistance measurements of Section 1.10.1 on each thermocouple assembly.

____ 1.10.3 Radiography (fuel pin center and end cap thermocouple assemblies only)

The first 12 inches from the hot junction end of the thermocouple assembly shall be radiographed. Radiograph quality shall permit sheath, wires, and hot junction inspection. If the final thermocouple assembly configuration, as determined by the radiograph, does not meet the dimensional specifications of the applicable design drawings, the assembly shall be rejected, unless otherwise specified by the Project Manager.

Three radiographs shall be made of each thermocouple assembly, at 0° , 60° , and 120° . Radiographs shall be identified in a manner that will permit matching with the correct thermocouple assembly. Thermocouples shall be marked in a manner that will permit later identification of the wire orientation within the thermocouple sheath, to permit bending of the thermocouple in the plane perpendicular to the plane through the two wires in the two wire thermocouple assemblies, and perpendicular to the two parallel planes for the four wire thermocouple assemblies.

____ 1.10.4 Leakage Resistance

The resistance between each wire and the sheath of the fuel pin center and end cap thermocouple assemblies shall be measured under an applied potential of 500 volts. The test shall be performed before and after the thermocouple assemblies are bent to the configurations specified on applicable drawings. For thermocouple assemblies that do not require bending, perform only one leakage resistance test.

Progressively increase the voltage from 0 to 500 volts. Use a limiting resistor in series with the 500 volt supply, to limit the maximum short circuit current to less than 1 microampere. The resistance values shall exceed 1000 Meg ohm. Assemblies with resistance values less than 1000 Meg ohms shall be rejected, unless otherwise specified by the Project Manager.

APPENDIX B
Capsule Assembly Fabrication Procedures

2.0 CAPSULE ASSEMBLY FABRICATION PROCEDURES

Capsule Identification No. _____

Size Designation _____

Assembly Designation _____

Drawing No. _____ Rev. _____

2.1 Preparation

— 2.1.1 Select the following parts and verify complete material certification, inspection records and piece part fitup.

- _____ a) Fuel pin
- _____ b) End cap (inlet)
- _____ c) End cap (outlet)
- _____ d) Capsule tube (vibroetch ID no. per applicable drawing)
- _____ e) Positioning pins
- _____ f) Sleeves (*) (***)
- _____ g) Fuel center thermocouple assembly (inlet) (**)
- _____ h) Fuel center thermocouple assembly (outlet) (*) (**)
- _____ i) End cap thermocouple (inlet)
- _____ j) End cap thermocouple (outlet) (*)
- _____ k) No. 1 wall thermocouple assembly (hot junction nearest inlet end) (*)
- _____ l) No. 2 wall thermocouple assembly (hot junction nearest center)
- _____ m) No. 3 wall thermocouple assembly (hot junction nearest outlet end)

— 2.1.2 Clean parts a thru f in accordance with Section 5, Cleaning Procedures.
Note: When cleaning fuel pin, end protectors must be in place to prevent acid from entering thermowells or sleeve crevice. Caution: Inspect for cleaning fluid leakage and if present notify NASA Project Manager.

— 2.1.3 Assemble inlet fuel center thermocouple assembly with inlet end cap and weld in accordance with Procedure 4, Welding.

— 2.1.4 Assemble outlet fuel center thermocouple assembly with outlet end cap (align TC wires for proper bending angle) and weld in accordance with Procedure 4, Welding.

— 2.1.5 Assemble inlet end cap thermocouple assembly with inlet end cap.
Cover tantalum section of fuel center thermocouple with tantalum and weld end cap thermocouple to end cap in accordance with Procedure 4, Welding.

* Not required on L/3 capsules

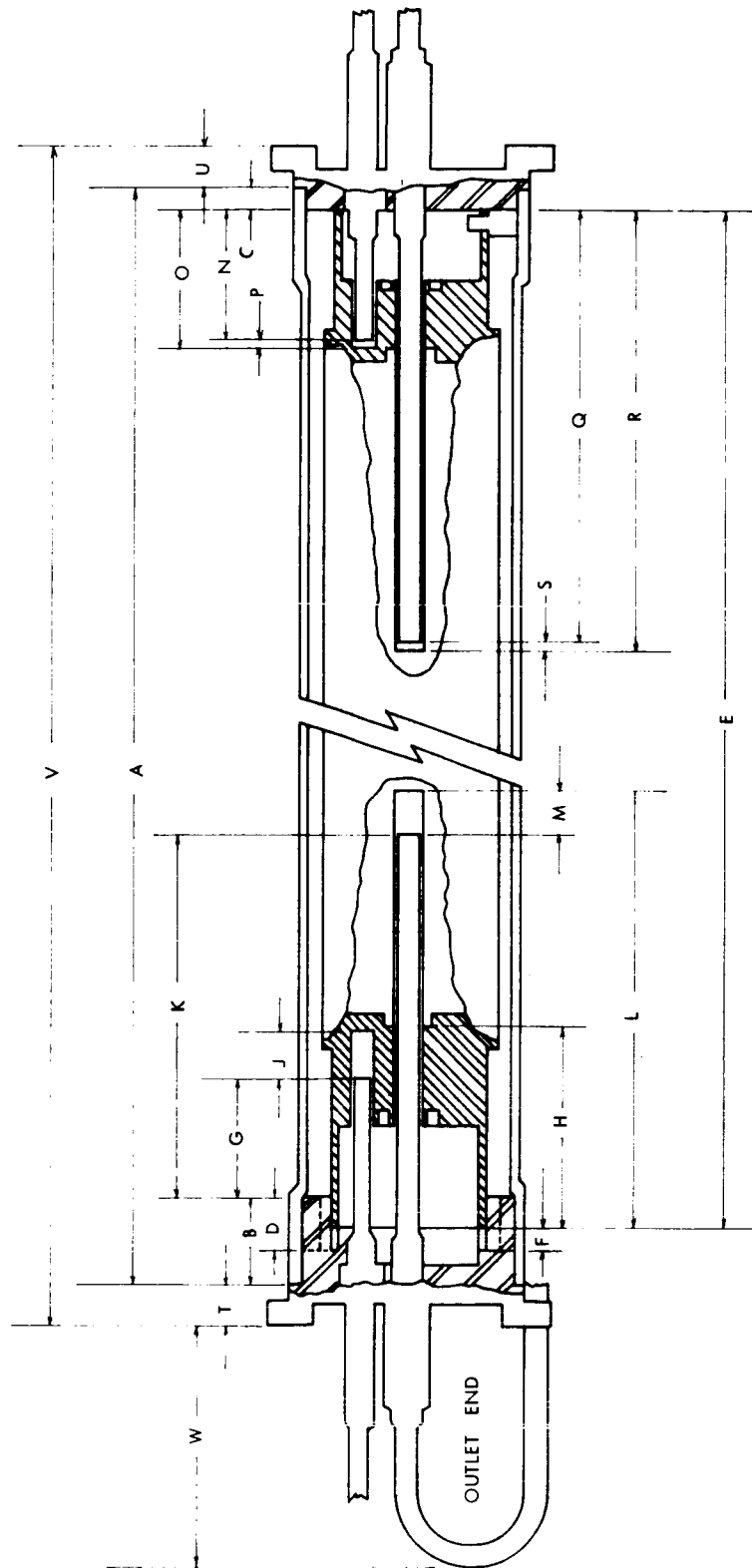
** Not required on L-P capsules

*** Not required on L-I capsules

- ___ 2.1.6 Assemble outlet end cap thermocouple assembly with outlet end cap and align TC wires for proper bending angle. Cover tantalum section of fuel center thermocouple with tantalum and weld end cap thermocouple to end cap in accordance with Procedure 4, Welding.
- ___ 2.1.7 Mass spectrometer helium leak check end cap thermocouple sub-assemblies.
- a) Outlet end - leak detector calib. _____
leak rate _____
- b) Inlet end - leak detector calib. _____
leak rate _____
- Note: Max allowable leak rate = 1×10^{-8} std. cc/sec
- ___ 2.1.8 Complete the proper data sheet for Sketch B-1, B-2 or B-3 for the type of capsule under construction.
- ___ 2.1.9 Test assemble each end cap-thermocouple well subassembly with fuel pin to insure alignment of holes in capsule end cap and fuel pin spacer sleeve.
- ___ 2.1.10 Determine radial gap clearances between fuel pin OD and capsule ID and record on capsule pre-irradiation data sheet Section 3.4.
- ___ 2.1.11 Scribe an alignment mark at each end of capsule tube and on inlet and outlet end caps so that when marks are aligned thermocouples are positioned as specified in applicable drawings.
- 2.2 Capsule Assembly (Note: Handle fuel pin and capsule internal parts as specified in Section 5.1.5 of Cleaning Procedures)
- ___ 2.2.1 Clamp capsule tube in the vertical position with inlet end up.
- ___ 2.2.2 Insert a section of pre-cleaned and pre-measured .002 thick Ta foil into ID of capsule tube and let it expand against the tube wells. Ta foil weight _____. Two or three inches of foil should extend out the inlet end.
- ___ 2.2.3 Wrap TC lead wire on rotating fixture reel.
- ___ 2.2.4 Mate inlet end cap assembly with inlet end of fuel pin using extreme care as TC wells are inserted into fuel pin wells. Install locking pins through end cap tabs and fuel pin sleeve.

L-I Capsule No.

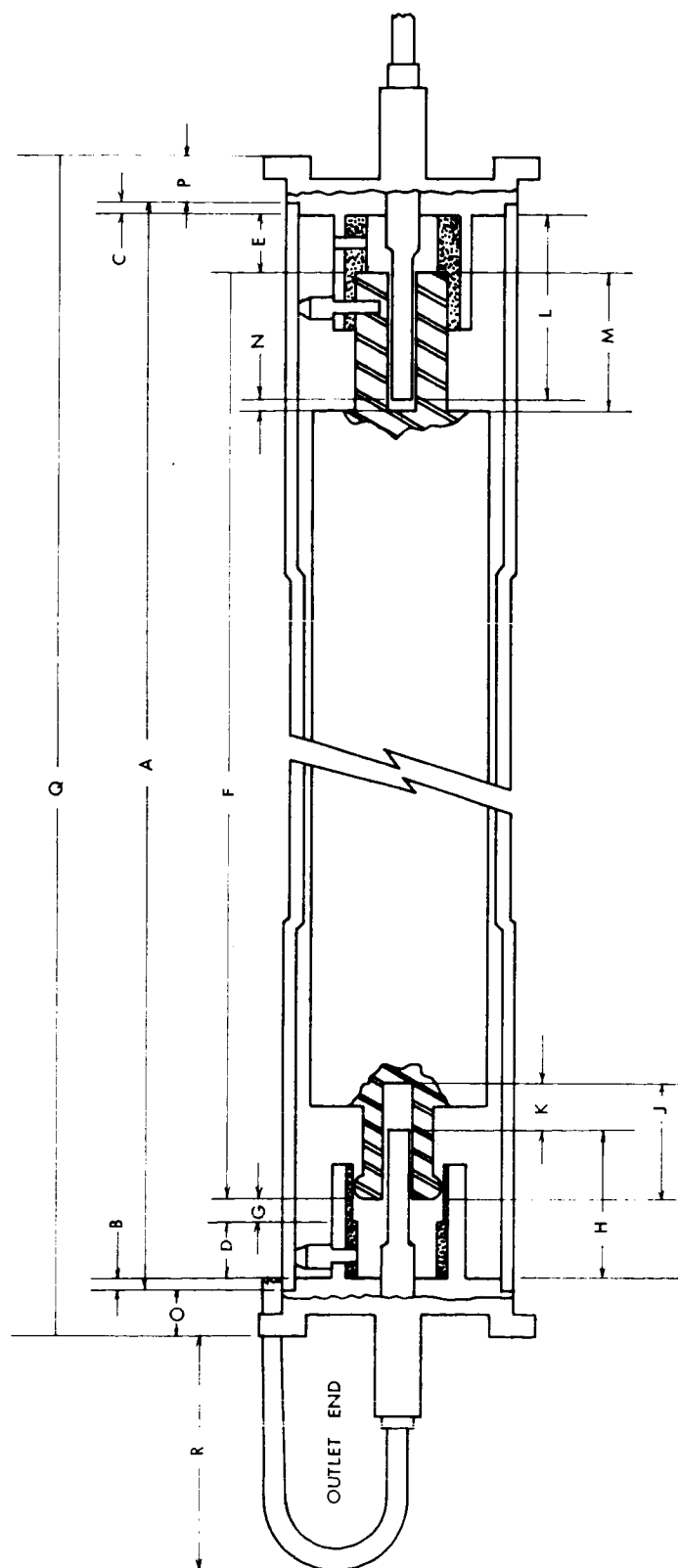
Reference Sketch L-I	Description	Nominal Tol.	Dimension Before Welding	Dimension After Welding	Out of Tolerance
A	Capsule Tube Length	18.230 +.005 -.000		--	
B	Outlet End Cap Insert Depth	.390 ±.005		--	
C	Inlet End Cap Insert Depth	.075 ±.005		--	
I	Distance Between End Caps (inside) A-(B+C)	17.765			
D	Outlet End Cap (inside) to Fuel Pin Stop	.215 ±.005		--	
II	Length Inside Capsule Available for Fuel Pin I+D	17.980			
E	Fuel Pin Length	17.88 ±.01		--	
F	Distance Available for Differential Expansion II-E	.100			
G	Length of End Cap TC Inside Outlet End Cap	.635		--	
H	Depth of End Cap TC Well in Fuel Pin Outlet End	.860		--	
J	Distance Between End of TC and Bottom of TC Well Outlet End - End Cap TC H-(G+D-F)	.110			
K	Length of Fuel Center TC Inside Outlet End Cap	3.195		--	
L	Depth of Fuel Center TC Well in Fuel Pin Outlet End	3.420		--	
M	Distance Between End of TC and Bottom of TC Well Outlet End-Fuel Center L-(K+D-F)	.110			
N	Length of End Cap TC Inside Inlet End Cap	.581		--	
O	Depth of End Cap TC Well in Fuel Pin Inlet End	.590		--	
P	Distance Between End of TC and Bottom of TC Well Inlet End-End Cap TC O-N	.009 min .003 max .015			
Q	Length of Fuel Center TC Inside Inlet End Cap	3.124		--	
R	Depth of Fuel Center TC Well in Fuel Pin Inlet End	3.150		--	
S	Distance Between End of TC and Bottom of TC Well Inlet End-Fuel Center R-Q	.026 min .003 max .050			
T	Outlet End Cap Thickness Minus Insertion Step	.175		--	
U	Inlet End Cap Thickness Minus Insertion Step	.175		--	
V	Capsule Length Before Welding (A+T+U) Capsule Length After Welding (Measurement)	18.580 18.570	--	--	
W	Distance from Outlet TC Bend to End Cap B-4		--		



Sketch B-1. L-1 Capsule

L-P Capsule No.

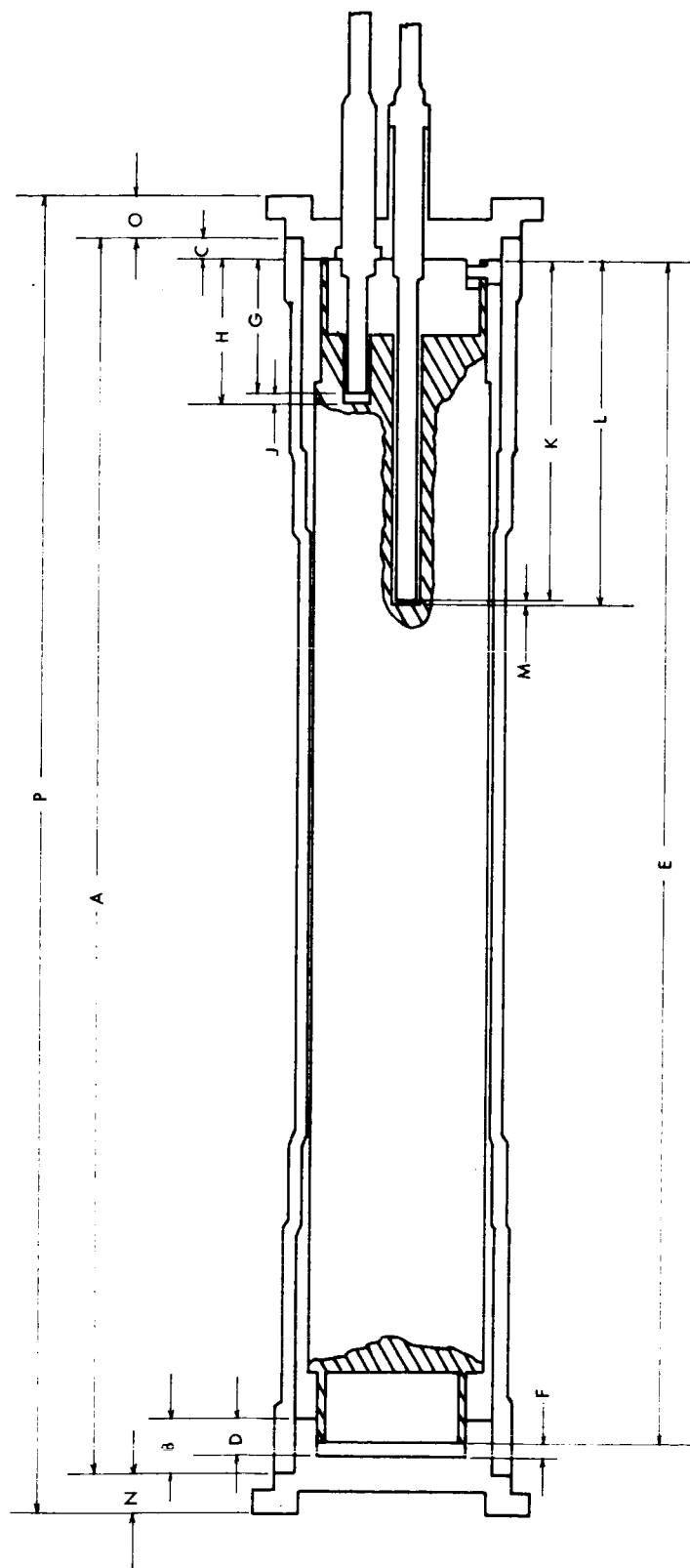
Reference Sketch L-P	Description	Nominal Tol.	Dimension Before Welding	Dimension After Welding	Out of Tolerance
A	Capsule Tube Length	18.230 +.005 -.000		--	
B	Outlet End Cap Insert Depth	.075 ±.005		--	
C	Inlet End Cap Insert Depth	.075 ±.005		--	
I	Distance Between End Caps (inside) A-(B+C)	18.080			
D	Outlet End Cap (inside) to Fuel Pin Stop	.250 ±.005		--	
E	Inlet End Cap (inside) to Fuel Pin Stop	.250 ±.002		--	
II	Length Inside Capsule Available for Fuel Pin I-(D+E)	17.580			
F	Fuel Pin Length	17.490 ±.010		--	
G	Distance Available for Differential Expansion II-F	.090			
H	Length of TC inside Outlet End Cap	.694		--	
J	Depth of Fuel Pin TC Well (Outlet End)	.464 +.000 -.002		--	
K	Distance Between End of TC and Bottom of TC Well (J+D+G)-H (Outlet End)	.110 min .073			
L	Length of TC inside Inlet End Cap	.811		--	
M	Depth of Fuel Pin TC Well (Inlet End)	.569 +.001 -.000		--	
N	Distance Between End of TC and Bottom of TC Well (E+M)-L (Inlet End)	.008 min .003 max .015			
O	Outlet End Cap Thickness Minus Insertion Step	.175 ±.005		--	
P	Inlet End Cap Thickness Minus Insertion Step	.175 ±.005		--	
Q	Capsule Length Before Welding (A+O+P) Capsule Length After Welding (Measurement)	18.580 18.570	--	--	
R	Distance from Outlet TC Bend to End Cap	.99 max	--		



Sketch B-2. L-P Capsule

L/3 Capsule No.

Reference Sketch L/3	Description	Nominal Tol.	Dimension Before Welding	Dimension After Welding	Out of Tolerance
A	Capsule Tube Length	5.377 +.005 -.000		--	
B	Outlet End Cap Insert Depth	.225 ±.005		--	
C	Inlet End Cap Insert Depth	.075 ±.005		--	
I	Distance Between End Caps (inside) A-(B+C)	5.077			
D	Outlet End Cap (inside) to Fuel Pin Stop	.150 ±.005		--	
II	Length Inside Capsule Available for Fuel Pin I+D	5.227			
E	Fuel Pin Length	5.167 ±.010		--	
F	Distance Available for Differential Expansion II-E	.060			
G	Length of End Cap TC Inside Inlet End Cap	.581		--	
H	Depth of End Cap TC Well Fuel Pin Inlet End	.590		--	
J	Distance Between End of TC and Bottom of TC Well Inlet End-End Cap TC H-G	.009 min .003 max .015			
K	Length of Fuel Center TC Inside Inlet End Cap	1.394		--	
L	Depth of Fuel Center TC Well Fuel Pin Inlet End	1.420		--	
M	Distance Between End of TC and Bottom of TC Well Inlet End-Fuel Center L-K	.026 min .003 max .050			
N	Outlet End Cap Thickness Minus Insertion Step	.175		--	
O	Inlet End Cap Thickness Minus Insertion Step	.175		--	
P	Capsule Length Before Welding A+N+O Capsule Length After Welding (Measurement)	5.727 5.717	--	--	



Sketch B-3. L/3 Capsule

- 2.2.5 Holding end cap-fuel pin-TC subassembly firmly together insert outlet end of fuel pin into inlet end of capsule tube and push through until inlet end cap is seated. (Note: align reference scribe marks).
- 2.2.6 Remove Ta foil from outlet end and inspect to insure that all of it has been removed from capsule. Ta foil weight _____.
- 2.2.7 Insert the outlet end centering spacer making certain that fuel pin is properly engaged.
- 2.2.8 Make a bead on tube process control weld (tube to be the same size and wall thickness of capsule tube) for capsule to end cap configuration with the same parameters indicated in Procedure 70916-6 of Section 4.0 Welding. Inspect weld for appearance and penetration. Welders evaluation of Weld _____.
- 2.2.9 Rotate capsule to the horizontal position and install in welding fixture. Approximate center of capsule shall be clamped in 3 jaw chuck and inlet end cap - TC subassembly supported and spring pressure applied with rotating tail stock fixture.
- 2.2.10 Making sure scribe marks (end cap to capsule tube) are aligned EB tack weld inlet end cap to capsule tube then EB weld all around per Procedure 4, Welding.
- 2.2.11 Remove capsule subassembly from welding chamber (Note: Allow at least 1/2 hour after welding for assembly to cool before breaking to air) and remove capsule subassembly from welding fixture.
- 2.2.12 Turn capsule subassembly around in chuck so that outlet end is facing tail stock. Rotate welding fixture so that capsule is in the vertical position with outlet end up.
- 2.2.13 Wrap TC lead wires on rotating fixture reel.
- 2.2.14 Remove the outlet end centering spacer and carefully install the outlet end cap subassembly into capsule. Align scribe marks.
- 2.2.15 Rotate welding fixture with capsule assembly back into the horizontal position and apply spring pressure against outlet end cap with tail stock fixture.
- 2.2.16 Insure that scribe marks are aligned and EB tack weld end cap in place. EB weld all around per Procedure 4.0, Welding. Visually inspect welds. Results _____.

2.3 Sealing Capsule

- ___ 2.3.1 While maintaining capsule in the EB welding fixture, position electrode to the seal hole.
- ___ 2.3.2 Evacuate chamber to 5×10^{-5} torr or better and continue evacuating for a minimum of 2 hours (preferably overnight).
- ___ 2.3.3 Backfill chamber with certified ultrahigh purity helium.
- ___ 2.3.4 Monitor and record chamber O_2 _____ and H_2O _____. Note: O_2 and H_2O level must be below 5.0 ppm before proceeding.
- ___ 2.3.5 Record chamber temperature _____ and pressure _____. (Press. to be 13 to 15 psia.)
- ___ 2.3.6 Make seal weld in accordance with Procedure 4.0, Welding.

2.4 Capsule Inspection

- ___ 2.4.1 Remove sealed capsule from chamber and immediately mass spectrometer leak check.
 - a) Leak detector calibration (smallest detectable leak) _____.
 - b) Capsule leak rate _____.
- ___ 2.4.2 Visually inspect capsule seal and end cap welds. Result _____
- ___ 2.4.3 Dye penetrant inspect seal and end cap welds. Result _____
- ___ 2.4.4 X-ray capsule assembly at 0° and 90° .
- ___ 2.4.5 Calibrate installed thermocouples at $535^\circ K$ ($500^\circ F$).

	Inlet TCs		Outlet TCs		Reference TC
	End Cap	Fuel Center	End Cap	Fuel Center	
Loop Resistance (ohms) at room temp.					
Insulation resistance (ohms) at room temperature					
Thermocouple reading ($^{\circ}\text{F}$) at room temperature					
Thermocouple reading ($^{\circ}\text{F}$) at 535°K (500°F)					
Loop resistance (ohms) at 535°K (500°F)					
Insulation resistance (ohms) at 535°K (500°F)					

2.5 Wall Thermocouple Installation and Final Resistance Checks

— 2.5.1 Install wall thermocouples in accordance with Procedure 4, Welding & Soldering.

— 2.5.2 Check each thermocouple after installation for temperature response.

— 2.5.3 Bend fuel center and end cap thermocouples in accordance with applicable drawings. Bend each thermocouple in 10° increments with a 10 second wait period between each 10° bend increment. Use bending fixture designed for each bend. Check that capsule assembly and thermocouples fit protective shroud tube after bending.

— 2.5.4 Proof pressure test by pressurizing capsule assembly to 225 psig for 30 minutes with helium. Immediately after releasing pressure, bubble check capsule assembly by submerging in alcohol then transfer to the leak detection chamber within 15 minutes. Mass spectrometer helium leak check. (Maximum allowable leak rate = 1×10^{-8} std. cc/sec).

a) Leak detector calibration _____ std. cc/sec

b) Capsule leak rate _____ std. cc/sec

— 2.5.5 Spot weld protective Nichrome foil over wall thermocouple attachment and thermocouple lead hold down straps in accordance with applicable drawing and Procedure 4, Welding and Soldering.

___ 2.5.6 Make leakage resistance measurements on thermocouples bent in 2.5.3.
as specified in Procedure 1.10.4.

___ 2.5.7 Measure and record loop resistance to the nearest .01 ohm.

- a) Ambient temperature _____ (all TC's to be at ambient temperature)
- b) Inlet end cap TC _____ ohms
- c) Inlet fuel center TC _____ ohms
- d) Outlet end cap TC _____ ohms
- e) Outlet fuel center TC _____ ohms
- f) No. 1 wall TC _____ ohms
- g) No. 2 wall TC _____ ohms
- h) No. 3 wall TC _____ ohms

APPENDIX C
Pre-Irradiation Capsule Data

3.0 PRE-IRRADIATION CAPSULE DATA

3.1 Capsule Data

3.1.1 Capsule identification no. _____

3.1.2 Fuel pin identification no. _____

3.1.3 Size designation _____

3.1.4 Assembly designation _____

3.1.5 Assembly drawing no. _____ Rev. _____

3.2 Capsule Tube Dimensions (⊙ Identification No. _____)

3.2.1 Tube length _____

a) Tube straightness _____

3.2.2 I.D. & O.D. at "C" Dia L/3 capsules or "V" Dia. L Capsules

	Max.	Min.	Avg.
O.D.			
I.D.			

3.3 Fuel Pin O.D. Measurements

Max. _____ Min. _____ Avg. _____

3.4 Helium Gap Between Fuel Pin and Capsule at "C" Dia. L/3 Capsules or "V" Dia. L Capsules

Max. _____ Min. _____ Avg. _____

3.3.1 Fuel pin wt (including sleeves) after final cleaning _____

3.5 Capsule Closure

3.5.1 Helium pressure _____ psia temperature _____ °F

3.5.2 Helium purity (ppm) from batch analysis

- a) H _____
- b) Ne _____
- c) N _____
- d) O₂ _____
- e) CO₂ _____
- f) H₂O _____
- g) _____
- h) _____

3.5.3 Helium purity (ppm) Westinghouse spot check

a) O₂ _____
 b) H₂O _____

3.6 Thermocouple Data

	Inlet End Cap TC	Inlet Fuel Center TC	Outlet End Cap TC	Outlet Fuel Center TC	Wall No. 1 TC	Wall No. 2 TC	Wall No. 3 TC
Identification No.							
Loop Resistance Ambient Temperature (Initial)							
(Final)							
Insulation Resistance Ambient Temperature (Initial)							
(Final)					-	-	-
Loop Resistance Elevated Temperature							
Insulation Resistance Elevated Temperature							

3.7 Capsule Dimensions (After Welding)

3.7.1 Capsule length from outside of end caps _____

3.7.2 Capsule straightness _____ (.004" max.)

Radial Position	Axial Traverse by Dial Indicator from a Flat Parallel Surface									
	Outlet End	2"	4"	6"	8"	10"	12"	14"	16"	Inlet End
0°										
90°										

3.7.3 Internal clearance between end of fuel pin and capsule end cap
 stop _____

3.7.4 Distance from outlet thermocouple bend to outside end of end cap

3.8 Inspection

3.8.1 Visual _____ Date _____ Initial _____

3.8.2 Ident. No. _____ Date _____ Initial _____

3.8.3 Final helium leak check _____ Date _____ Initial _____

Leak detector calibration (minimum detectable leak) _____

Capsule leak rate _____

3.8.4 Dye penetrant _____ Date _____ Initial _____

3.8.5 X-ray _____ Date _____ Initial _____

3.8.6 Thermocouple 500°F Calib. _____ Date _____ Initial _____

Signed _____

Date _____

APPENDIX D

Welding and Soldering

4.0 WELDING AND SOLDERING

4.1 Fusion Welding

The principal document applied in the control of all fusion welding, either electron beam or tungsten arc, is WANL process specification PS 294614-1 (attached). This specification defines general weld quality requirements as revealed by visual, dye penetrant and radiographic (where applicable) inspection.

Helium leak testing is also performed at various assembly stages as noted in Procedures 1 and 2.

The welding specification defines the requirements for procedure qualification prior to production welding. Two sample parts must be produced with the final parameters to demonstrate capability. A "Welding Procedure Sheet" is prepared for each weld joint, defining the techniques employed. The eight procedure sheets required for this program are attached.

4.2 Soldering (Attachment of Thermocouple to Capsule Wall)

- 4.2.1 Check and record all thermocouple resistances.
- 4.2.2 Lightly abrade thermocouple sheath for removal of oxides in area to be soldered using 600 grit papers. Remove all oils and grease from the surfaces to be soldered with M-6 solvent followed by an ethyl alcohol rinse.
- 4.2.3 Using stainless-to-stainless flux and 50-50 (Pb-Sn) solid solder, 1/16"-1/8" diameter, tin and fill the slots of the fuel capsule walls. The heat source shall be a Weller D 440 solder gun. Do not tin more than 1/16" of walls adjacent to the slots. Remove flux with an ethyl alcohol rinse.
- 4.2.4 Tin, using flux and solder noted above, the portion of thermocouple sheath that will rest in the fuel capsule slots, and wash away all flux using an ethyl alcohol rinse.
- 4.2.5 Place a 1" x 1/16" tip of an \approx 350 watt soldering iron along the length of the solder filled slot in the capsule wall. As solder becomes a molten pool, insert pre-tined thermocouple sheath end into slot. Hold in position until filleting is apparent and then remove soldering irons. Do not move thermocouple as solidification occurs.
- 4.2.6 Remove excess solder, if necessary, using a 1" diameter x 1/8" thick stainless steel rotary brush.
- 4.2.7 Bend the thermocouple sheath to lie flat against the capsule wall.

4.2.8 Inspection

- a) Solder fillets shall be pore free (visual inspection) and shall not exceed 1/16" past the edges of the machined groove in the capsule wall.
- b) The maximum projection from the capsule wall shall be .080 inch.

4.3 Spot Welding of Protective Ribbon Over Thermocouple Ends

4.3.1 Prepare a 1/2" wide Nichrome ribbon long enough to cover the entire fuel capsule slot and extend 1/4" beyond the thermocouple end as defined on applicable drawings.

4.3.2 Spot weld ribbon to capsule using the following minimum weld pattern:
sides - 1/8" spacing one row each side closest to T/C - 1/4" spacing one row each side near edge of Nichrome strip. End: 1/8" spacing - locate as shown on PF-10651.

4.3.3 Spot Weld Technique

- a) Equipment: Unitek Model 1016C or equivalent.
- b) Procedure: Establish settings (watt seconds and pressure) for a given tip material and configuration prior to actual welding. Individual spots should pull nuggets when foil is separated from base material. Expulsion (spitting) is not permitted.

UNCLASSIFIED

Authorized Classifier Date 9/10/64



Westinghouse Electric Corporation

Astronuclear Laboratory
P. O. Box 10864
Pittsburgh, Pa. 15236
(Fed. Ident. Code No. 14683)

*PROCESS SPECIFICATION 294614, Revision No. 1
(Not for Publication)

November 21, 1968

WELDING, FUSION - AUSTENITIC STAINLESS STEELS FOR POWER GENERATING SYSTEMS

1. SCOPE

This specification covers requirements for fusion welding of austenitic stainless steels by the inert-gas tungsten arc, inert-gas metal arc, or electron beam process, intended for liquid metal or radioisotope heat source power generating systems, designated as follows:

<u>Designation</u>	<u>Description</u>
294614-1	Fusion welding of AISI 300 series stainless steels for systems requiring sound welds with no surface defects as indicated by liquid penetrant inspection.
294614-2	Fusion welding of AISI 300 series stainless steels for systems requiring sound welds with less restrictive surface quality requirements than 294614-1.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect, shall form a part of this specification to the extent specified herein.

MIL-T-5021 MIL-E-19933 MIL-STD-271 PS 294564 PDS 52118AE

2.2 Copies of MIL Specifications and Standards required by contractors in connection with specific procurement functions should be obtained as indicated in the Department of Defense Index of Specifications and Standards.

3. REQUIREMENTS

3.1 SAFETY: Some of the materials and/or operations required by this specification may be hazardous. The vendor is requested to consult a qualified Safety or Industrial Hygiene Engineer for necessary precautions. If processed by a Westinghouse plant, the instructions in Safe Practice Data Sheet, for example, Sheet W-1, shall be consulted to obtain information regarding the nature and properties of any material or processing requirement to avoid accident to employees or damage to equipment.

Printed in U.S.A.

GDR/mms

Page 1 of 5 Pages

D-4

3.2 MATERIAL AND EQUIPMENT

3.2.1 Maintain all equipment including accessories, holders, leads, ground connections and any other equipment necessary to fulfill requirements of this specification at a level such that welds meeting the quality standards of this specification may be consistently produced. Maintenance within minimum accepted safety requirements is also required.

3.2.2 The welding area shall be protected from air movement due to fans, welding generators, open windows, exhaust hoods, etc.

3.2.3 The materials shall be as specified on the applicable drawing.

3.3 SURFACE PREPARATION: All foreign material shall be removed from both sides of the area that is to be welded or that will be heated by the welding.

3.3.1 All parts shall be free of grease and oil and other possible contaminants such as marking crayons, layout dyes, inks and similar materials prior to welding.

3.3.2 All oxides shall be removed from the immediate vicinity of the area to be welded. Extreme care shall be exercised in the cleaning procedures applied to each restrike area and to each completed weld prior to application of the next bead. All grit residue shall be removed with a clean, stainless steel wire brush prior to further welding. Pits or laps shall be blended mechanically before welding over them.

3.4 PROCESS

3.4.1 Manual or automatic inert-gas shielded tungsten arc or inert-gas metal arc processes, or the electron beam process shall be used.

3.4.2 Wherever feasible, grooved back-up bars or inert-gas backing shall be employed.

3.4.3 For tungsten arc welding, the electrode shall be the thoriated type and dressed to a point the diameter of which is one half that of the base.

3.4.4 Unless otherwise specified, the filler wire shall be as follows:

<u>Base Material</u>	<u>Filler Wire</u>
AISI 304	MIL-E-19933, Type 308
AISI 304L	MIL-E-19933, Type 308L
AISI 310	MIL-E-19933, Type 310
AISI 316	MIL-E-19933, Type 316
AISI 316L	MIL-E-19933, Type 316L
AISI 321	MIL-E-19933, Type 308L or 347
AISI 347 or 348	MIL-E-19933, Type 308L or 347

3.4.5 Shielding and backup gas shall be welding grade argon as specified by PDS 52118 AE.

3.4.6 Each weld pass shall be visually inspected and any porosity, surface cracks or oxide removed prior to additional welding (See Section 3.3).

3.5 PROCEDURE QUALIFICATION

3.5.1 The detailed welding procedure shall be qualified for production welding of parts covered by this specification by producing a minimum of two acceptable welds simulating actual production welding position and conditions. The qualification welds shall be made on parts which simulate the heat sink and joint configuration of the actual parts.

3.5.2 The qualification welds shall conform to the applicable quality requirements of Section 4.4.

3.5.3 At least one cross section through each of the qualification welds shall be polished and etched. These sections shall reveal no cracks, excessive oxide, lack of penetration or incomplete fusion.

3.5.4 The detailed welding procedure used in producing the qualification welds shall be documented and include all appropriate weld parameters, joint configuration, and all pertinent information of welding power source, torch, and accessory equipment and be submitted to the purchaser for approval prior to production welding. The results of the required quality control inspection shall also be included.

3.6 PERSONNEL QUALIFICATION:

3.6.1 (294614-1) Manual welding shall require qualification according to the detailed procedure defined in Section 3.5, and shall require qualification according to MIL-T-5021 for the applicable material.

3.6.2 (294614-2) For manual welding, the operator performing a procedure qualification as defined in Section 3.5 shall be considered qualified. Once the procedure has been approved, any operator certified to MIL-T-5021 for the applicable material may perform production welds using the approved procedure for a given joint configuration.

4. QUALITY ASSURANCE

4.1 SURVEILLANCE: Adherence to the provisions of this specification shall be under the surveillance of a Westinghouse Quality Control representative.

4.2 COMPLIANCE: No change shall be made from this specification, or an approved procedure, without first obtaining written approval of the purchaser.

4.3 PRODUCTION WELDING: Production welding shall be performed using only an approved procedure and a qualified operator for manual welding.

4.4 INSPECTION

4.4.1 Liquid Penetrant

4.4.1.1 (294614-1): Both sides of the root pass (if accessible) and the surface of the final weld pass, shall be penetrant inspected in accordance with 294564-1 and shall conform to class O acceptance standard.

4.4.1.2 (294614-2): Both sides of the root pass (if accessible) and the surface of the final weld pass shall be liquid penetrant inspected in accordance with 294564-1 and shall conform to the following:

4.4.1.2.1 No cracks or crack type indications shall be permitted.

4.4.1.2.2 The weld shall conform to 294564-1, class 3-2A requirements.

4.4.2 Visual: The weld surface shall be smooth, free of cracks, laps, and unfused areas. No undercut or depressions below the level of the base metal shall be permitted on the face or root of the weld. For butt welds a maximum of 0.050 inch root reinforcement and a minimum total weld thickness of 125% of the base metal thickness is required unless otherwise specified by the drawing. A visible smooth 100% penetration shall be required at the root of all welds exposed to liquid metals.

4.4.3 Radiography: When specified by an applicable drawing, radiographic inspection shall be conducted on all qualification and production welds. The inspection shall be in accordance with MIL-STD-271. Acceptance criteria are as follows:

4.4.3.1 (294614-1) Indications of defects or discontinuities on a radiograph shall be referred to the responsible engineer for his review and disposition.

4.4.3.2 (294614-2) The following shall be cause for rejection:

4.4.3.2.1 Cracks.

4.4.3.2.2 Lack of fusion or root penetration.

4.4.3.2.3 Porosity or inclusions with sharp tails.

4.4.3.2.4 Linear porosity or inclusions. Linear porosity is defined as the condition in which three (3) or more indications having a diameter 1/32 inch or over intersect a straight line parallel to the longitudinal axis of weld and their distance of closest approach is less than 1/8 inch.

4.4.3.2.5 The scattered porosity and inclusion standard shall be as follows:

<u>Minimum Thickness of Materials Being Joined</u>	<u>Maximum Allowable Void Diameter</u>	<u>Minimum Allowable Spacing</u>	<u>Maximum Frequency (indications of any size per inch of weld)</u>
0 - 1/4"	1/3 T or 3/64" (whichever is less)	3 times the diameter of the largest of any two adjacent defects.	4
1/4 - 3/8"	1/4 T	"	6

4.5 REPAIR

4.5.1 Weld defects in excess of the requirements of Section 4.4 shall be removed using a small carbide burr, grinding wheel, or file.

4.5.2 The weld shall be liquid penetrant inspected in accordance with 294564-1 to insure complete removal of the defect. If this inspection reveals the continued presence of the defect, Section 4.5.1 shall be repeated.

4.5.3 All penetrant and developer shall be removed prior to rewelding by wiping with a clean, lint-free cloth saturated with methanol or other equivalent solvent.

4.5.4 Where complete removal of surface defects can be accomplished by the removal of metal such that the weld still meets all size and quality requirements, no further repair work shall be required.

4.5.5 All weld repairs shall meet the quality requirements of Section 4.4 of this specification.

4.6 REPORTS: A report shall be prepared covering the welding of each assembly or subassembly and submitted to the responsible engineer. The minimum content shall be the date, equipment identification, details of welding procedure, identification of parts by name and number, operator qualification details and date qualified, and a statement that the welds conformed to the requirements of Section 4.4.

Procedure No.: 70916-1

Date: 6/21/71

WELDING PROCEDURE

Name of Part Thermocouple Well End Plug Drawing No. PF 10652

Welding Spec. No. --

Material Tantalum Material Spec. No. --

Description of Welds Covered by this Procedure Edge weld-plug inserted flush with end of
(type, size, location)
tantalum tube.

Welding Process Electron Beam

Welding Machine Hamilton Zeiss (2 KW) Type Current --

Electrode - Type -- Size -- Spec. --

Filler Material - Comp. -- Spec. --

Shielding Gas Vac. - 1×10^{-4} mm Hg Backup Gas --

Cleaning Prior to Welding Handle only with clean lint free gloves. Parts will come to weld area
pre-cleaned. Contact only with Moly or Ta tools, fixtures or handling devices.

Detailed Procedure:	<u>A</u>		<u>B</u>	
	3/32 OD x .007 wall tube	Pass	5/32 OD x .010 wall tube	Pass
Current	<u>2 milliamps</u>	<u> </u>	<u>2.5 milliamps</u>	<u> </u>
Voltage	<u>75 KV</u>	<u> </u>	<u>75 KV</u>	<u> </u>
Filler Wire Size	<u> </u>	<u> </u>	<u> </u>	<u> </u>
Filler Feed Rate	<u> </u>	<u> </u>	<u> </u>	<u> </u>
Travel Speed	<u>34 RPM</u>	<u> </u>	<u>34 RPM</u>	<u> </u>
Interpass Temp.	<u> </u>	<u> </u>	<u> </u>	<u> </u>
Weld Position	<u>Beam parallel to</u>	<u> </u>	<u>Beam parallel to</u>	<u> </u>
	<u>tube axis</u>	<u> </u>	<u>tube axis</u>	<u> </u>

Remarks (include details of fixturing, tacking where required, chills, etc.)

1. Manual start and taper
2. Work Distance \approx 1"
3. Deflection - none
4. Beam Location - on joint

Procedure No.: 70916-2

Date: 6/21/71

WELDING PROCEDURE

Name of Part Thermocouple Well Drawing No. PF 10652

Welding Spec. No. --

Material 304L St. St. to Tantalum Material Spec. No. --

Description of Welds Covered by this Procedure Fillet Between St. St. Tube and Tantalum Tube
(type, size, location)

Welding Process Electron Beam

Welding Machine Hamilton-Zeiss (2 KW) Type Current --

Electrode - Type -- Size -- Spec. --

Filler Material - Comp. -- Spec. --

Shielding Gas Vac. - 1×10^{-4} mm Hg (max.) Backup Gas --

Cleaning Prior to Welding Handle only with clean lint free gloves after cleaning per assembly procedures.

Detailed Procedure:	A	B	Pass
	3/32 OD Ta Tube	5/32 OD Ta Tube	
Current	<u>.9 MA</u>	<u>50 KV</u>	<u>50 KV</u>
Voltage	<u>50 KV</u>	<u>50 KV</u>	<u>50 KV</u>
Filler Wire Size	<u>--</u>	<u>--</u>	<u>--</u>
Filler Feed Rate	<u>--</u>	<u>--</u>	<u>--</u>
Travel Speed	<u>34 RPM</u>	<u>34 RPM</u>	<u>34 RPM</u>
Interpass Temp.	<u>--</u>	<u>--</u>	<u>--</u>
Weld Position	<u>Beam 11 to Tube Axis</u>	<u>Beam 11 to Tube Axis</u>	<u>Beam 11 to Tube Axis</u>

Remarks (include details of fixturing, tacking where required, chills, etc.)

1. 6" work distance
2. Manual beam taper after melt and filleting occur
3. Beam placed 80% on St. St. & 20% on Ta sheath

Procedure No.: 70916-3

Date: 6/21/71

WELDING PROCEDURE

Name of Part TC Sheath to TC Well (D Size) Drawing No. PF 10664

Welding Spec. No. --

Material 304 L-Well to 304 Sheath Material Spec. No. --

Description of Welds Covered by this Procedure Lap weld between outer wall of TC well
(type, size, location)
and .090" - .157" TC sheath

Welding Process Electron Beam

Welding Machine Sciaky Type Current --

Electrode - Type -- Size -- Spec. --

Filler Material - Comp. None Spec. --

Shielding Gas Vac. - 1×10^{-4} mm Hg (max.) Backup Gas --

Cleaning Prior to Welding Pre-cleaned to assembly check-off procedure. Handle with clean,
lint free gloves.

Detailed Procedure:

	Pass	Pass	Pass
Current	<u>2 MA (max.)</u>	<u> </u>	<u> </u>
Voltage	<u>17 KV</u>	<u> </u>	<u> </u>
Filler Wire Size	<u> </u>	<u> </u>	<u> </u>
Filler Feed Rate	<u> </u>	<u> </u>	<u> </u>
Travel Speed	<u>50 RPM</u>	<u> </u>	<u> </u>
Interpass Temp.	<u> </u>	<u> </u>	<u> </u>
Weld Position	<u>Beam Vertical</u>	<u> </u>	<u> </u>

Remarks (include details of fixturing, tacking where required, chills, etc.)

1. Run beam on larger diameter at reduced filament current. As preheat occurs and edge
melting begins, gradually increase filament current to achieve maximum beam current and
move part to blend molten metal onto sheath. As soon as filleting occurs, quickly taper
beam using filament current control.

Procedure No.: 70916-4

Date: 6/21/71

WELDING PROCEDURE

PF 10650

Name of Part L&L/3 Capsule - End Cap to Well Drawing No. PF 10651

Welding Spec. No. _____

Material 304L St. St. Material Spec. No. --

Description of Welds Covered by this Procedure Shoulder Joint - .015 min. penetration
(type, size, location)
on .185 diameter tubular assembly.

Welding Process Electron Beam

Welding Machine Sciaky Type Current --

Electrode - Type -- Size -- Spec. --

Filler Material - Comp. None Spec. --

Shielding Gas Vac. - 1×10^{-4} mm Hg (max.) Backup Gas --

Cleaning Prior to Welding Pre-cleaned to assembly check-off procedure. Handle with clean,
lint free gloves.

Detailed Procedure:

	Pass	Pass	Pass
Current	<u>5 MA</u>	_____	_____
Voltage	<u>30 KV</u>	_____	_____
Filler Wire Size	_____	_____	_____
Filler Feed Rate	_____	_____	_____
Travel Speed	<u>50 RPM</u>	_____	_____
Interpass Temp.	_____	_____	_____
Weld Position	<u>Beam Vertical</u>	_____	_____

Remarks (include details of fixturing, tacking where required, chills, etc.)

1. Weld Program: Initial & Final Current - 1 MA, Initial & Final Slope Rate - 300,
Initial & Final Voltage - 14 KV, High Voltage Slope - 1, High Voltage Start Delay - .3 sec.,
Run Time - 2 sec., Decay Time - .5 sec.
2. Work Distance - 2" to bottom of scanner coil.

Procedure No.: 70916-5

Date: 6/23/71

WELDING PROCEDURE

Name of Part End Cap TC to Capsule End Cap Drawing No. PF 10650
PF 10651

Welding Spec. No. --

Material 304L St. St. Material Spec. No. --

Description of Welds Covered by this Procedure Butt Weld - 1/32" Penetration in .185" circle
(type, size, location)

Welding Process Electron Beam

Welding Machine Hamilton-Zeiss Type Current --

Electrode - Type -- Size -- Spec. --

Filler Material - Comp. -- Spec. --

Shielding Gas Vac. - 1×10^{-4} mm Hg (max.) Backup Gas --

Cleaning Prior to Welding Pre-cleaned to assembly check-off procedure. Handle with clean,
lint free gloves.

Detailed Procedure:

	Pass	Pass	Pass
Current	<u>2 MA</u>	<u> </u>	<u> </u>
Voltage	<u>120 KV</u>	<u> </u>	<u> </u>
Filler Wire Size	<u>--</u>	<u> </u>	<u> </u>
Filler Feed Rate	<u>--</u>	<u> </u>	<u> </u>
Travel Speed	<u>36 RPM</u>	<u> </u>	<u> </u>
Interpass Temp.	<u> </u>	<u> </u>	<u> </u>
Weld Position	<u>Beam 11 to TC axis</u>	<u> </u>	<u> </u>

Remarks (include details of fixturing, tacking where required, chills, etc.)

1. Work distance - 6 inches

2. Place protective Ta tube over TC and slide to position against end cap.

Procedure No.: 70916-6

Date: 9/22/71

WELDING PROCEDURE

Name of Part Capsule End Cap - Tube L & L/3 Length Drawing No. PF 10650
PF 10651

Welding Spec. No. --

Material 304L St. St. Material Spec. No. ---

Description of Welds Covered by this Procedure Butt Joint (.075 Min. Penetration)
(type, size, location)

Welding Process Electron Beam

Welding Machine Sciaky Type Current --

Electrode - Type -- Size -- Spec. --

Filler Material - Comp. -- Spec. --

Shielding Gas Vac. - 1×10^{-4} mm Hg/max.) Backup Gas --

Cleaning Prior to Welding Pre-cleaned and handled in assembly chamber as defined in
check-off procedure.

Detailed Procedure:

	1st Pass	2nd Pass	Pass
Current	<u>70 MA</u>	<u>20 MA</u>	<u>---</u>
Voltage	<u>30 KV</u>	<u>30 KV</u>	<u>---</u>
Filler Wire Size	<u>--</u>	<u>---</u>	<u>---</u>
Filler Feed Rate	<u>--</u>	<u>---</u>	<u>---</u>
Travel Speed	<u>50 RPM</u>	<u>30 RPM</u>	<u>---</u>
Interpass Temp.	<u>--</u>	<u>---</u>	<u>---</u>
Weld Position	<u>Capsule Horizontal,</u> <u>Beam Vertical</u>	<u>Same</u>	<u>---</u>

Remarks (include details of fixturing, tacking where required, chills, etc.)

1. Weld Program: Initial & Final Current - 5 MA, Initial & Final Slope Rate - 300,
Initial & Final Voltage - 14 KV, Voltage Slope - 2, Start Delay - .3 sec.,
Run Time - 1.7 sec (1st Pass), 2.7 sec. (2nd Pass), Decay Time - 1.5 sec.
2. Second Pass used only where required to eliminate undercutting at weld edge.
3. Work Distance - $\approx 6"$ to bottom of gun

Procedure No.: 70916-7

Date: 6/21/71

WELDING PROCEDURE

Name of Part D Capsule - Final Seal Weld Drawing No. PF 10650
PF 10651

Welding Spec. No. _____

Material 304 St. St. Material Spec. No. _____

Description of Welds Covered by this Procedure Arc Spot Seal of .030" dia. hole
(type, size, location)

Welding Process Tungsten arc

Welding Machine Merrick - 300 Amp - Amp Trak Type Current DCSP

Electrode - Type W (2% thoria) Size 3/32 Spec. --

Filler Material - Comp. -- Spec. --

Shielding Gas UHP Helium Backup Gas --

Cleaning Prior to Welding Pre-cleaned and handled in assembly chamber as defined in
check-off procedure.

Detailed Procedure:

	Pass	Pass	Pass
Current	<u>30 amps</u>	_____	_____
Voltage	_____	_____	_____
Filler Wire Size	_____	_____	_____
Filler Feed Rate	_____	_____	_____
Travel Speed	_____	_____	_____
Interpass Temp.	_____	_____	_____
Weld Position	<u>Perpendicular</u>	_____	_____

Remarks (include details of fixturing, tacking where required, chills, etc.)

Weld Current - 30 amps for 0.5 seconds then tapers to 10 amps during 0.5 seconds.

Amp Trak Settings - PFT = 0, IC = 30 amps, IT = 1 sec., WC (pendant) = 30 amps, WT = 0.5 sec.,

Taper-off, FST = 0.5 sec., PHC = 10 amps, PHT = 0, PET = 0

Arc Start Settings - One Shot (reset after each), Intensity = 60%

Procedure No.: 70916-8

Date: _____

WELDING PROCEDURE

Name of Part Seal Weld on Thermocouple Drawing No. PF 10

Welding Spec. No. _____

Material Ta Material Spec. No. _____

Description of Welds Covered by this Procedure Arc spot seal weld on Ta sheathed thermocouples
(type, size, location)

Welding Process Gas Tungsten Arc

Welding Machine Merrick - 300 amp - Amp Trac Type Current DCSP

Electrode - Type W (2% Thoria) Size _____ Spec. _____

Filler Material - Comp. -- Spec. --

Shielding Gas VHP Helium Backup Gas --

Cleaning Prior to Welding Pre-cleaned and handled in assembly chamber as defined in
check-off procedure.

Detailed Procedure:

	Pass	Pass	Pass
Current	_____	_____	_____
Voltage	_____	_____	_____
Filler Wire Size	_____	_____	_____
Filler Feed Rate	_____	_____	_____
Travel Speed	_____	_____	_____
Interpass Temp.	_____	_____	_____
Weld Position	<u>Downhand</u>	_____	_____

Remarks (include details of fixturing, tacking where required, chills, etc.)

- Moly chill must match sheath O.D. place chill
- 3/32 dia. -Amp Trak Settings - PFT = 0, IC = 10 amps, IT = 1 sec., WC (pendant) = 10 amps,
WT = 0.25 sec, Taper-off, FST = 0 PHC = 0, PHT = 0, PFT = 0
- 5/32 dia. -Amp Trak Settings - PFT = 0, IC = 35 amps, IT = 1 sec, WC (pendant) = 35 amps
WT = 0.25 sec Taper-off, FST = 0.5 sec, PHC = 10 amps, PHT = 0, PFT = 0
- Arc Start Settings - One shot, intensity = 60%
- Chill - Moly clamped within 1/2" of T.C. end.

APPENDIX E

Ti, Ta, Mo and Stainless Steel Cleaning Procedures

5.0 T-111, Ta, W, Mo AND STAINLESS STEEL CLEANING PROCEDURES

- 5.1 Refractory Metals Cleaning except for molybdenum (Note: Handle parts while cleaning only with refractory metal or teflon coated tongs. Also to assure optimum cleanliness, perform cleaning operation as near to time of use as practical.)

- 5.1.1 Degrease parts by M-6 solvent rinse or ultrasonic cleaning.
- 5.1.2 Pickle with nitric-hydrofluoric-sulfuric acid solution nominally 20-15-10% balance water by volume. Time one to two minutes at room temperature.
- 5.1.3 Rinse as follows (this is the most important step since pickling residues can cause surface contamination or degas severely on heating).
 - a) Fast transfer from pickle bath to rinse without any surface drying of pickle solution.
 - b) 30 seconds boiling distilled water.
 - c) 1 minute flowing cold water.
 - d) 5 minutes boiling distilled water (not the same water as in "b" above).
 - e) Fast rinse in ethyl alcohol.
 - f) Hot air flash dry.
- 5.1.4 Store in clean glass containers and/or in clean dry kim wipes. Polyethelene bags or other plastic containers not acceptable. Note: Clean glass containers by the same method used for cleaning stainless steel in 5.3.
- 5.1.5 Handle only with clean teflon coated tongs and tweezers or lint free gloves over pylox or quixams gloves.
- 5.1.6 Degas for 60 minutes at 2400°F wrapped in tantalum foil in vacuum 5×10^{-5} torr or better. Furnace cool to room temperature before removing.

5.2 Molybdenum Cleaning

- 5.2.1 Degrease parts by M-6 solvent rinse or ultrasonic cleaning.
- 5.2.2 Pickle in the following acid solution:
95 vol % sulfuric acid, 4.5 vol % nitric acid, 0.5% vol % hydrofluoric acid, 18.8 g/l chromic acid. 30-sec dip at 140 F.
- 5.2.2 Rinse for 1 minute in flowing cold water.
- 5.2.3 Rinse in boiling distilled water.
- 5.2.4 Wash with ethyl alcohol.
- 5.2.5 Hot air flash dry.

- 5.2.6 Store in clean glass containers and/or in clean dry kim wipes. Polyethelene bags or other plastic containers not acceptable. Note: Clean glass containers by the same method used for cleaning stainless steel in 5.3.
- 5.2.7 Handle only with clean teflon coated tongs and tweezers or lint free gloves over pylox or quixams gloves.
- 5.2.8 Degas for 1 hour at 1700°F wrapped in tantalum foil in vacuum 3×10^{-5} torr or better. Furnace cool to room temperature before removing.
- 5.3 Stainless Steel Cleaning (Note: To assure optimum cleanliness, perform cleaning operations as near to time of use as practical.)
- 5.3.1 Scrub with "Comet" cleanser. Note: Very small parts and parts with small holes and crevices cannot be effectively cleaned by this method.
- 5.3.2 Rinse in flowing hot tap water. Clean these parts in a clean ultrasonic tank using clean M-6 (oxylene) solvent for 15 minutes minimum then proceed to Step 4.
- 5.3.3 Rinse in boiling distilled water.
- 5.3.4 Wash with ethyl alcohol.
- 5.3.5 Air dry (hot air flash drying with heat gun acceptable).
- 5.3.6 Handle only with clean tools or lint free gloves over pylox or quixams gloves.
- 5.3.7 Store in clean glass containers and/or in clean dry kim wipes. Polyethelene bags or other plastic containers not acceptable.

APPENDIX F

Tools and Containers Cleaning Procedures

6.0 TOOLS, EQUIPMENT AND CONTAINERS CLEANING PROCEDURE

6.1 Tools and Fixtures for Handling Refractory Metals

- 6.1.1 All tools and fixtures that contact refractory metal parts for welding or final assembly must be constructed of refractory metal or coated with refractory metal.
- 6.1.2 Tools and equipment are to be cleaned prior to use by the methods described below.

6.2 Small Tools and Equipment Cleaning

- 6.2.1 Degrease all small tools and equipment by ultrasonic cleaning or M-6 rinse.
- 6.2.2 Rinse with ethyl alcohol.
- 6.2.3 Air dry (hot air flash drying with heat gun acceptable).

6.3 Large Tools, Equipment and Containers

- 6.3.1 Degrease by wiping with rag or kim wipe saturated with M-6 or other suitable solvent.
- 6.3.2 Wipe dry with clean rag or kim wipe.
- 6.3.3 Wipe with rag or kim wipe dampened with ethyl alcohol.
- 6.3.4 Air dry.

APPENDIX G

Capsule Assembly Packaging and Shipping Procedure

7.0 CAPSULE ASSEMBLY PACKAGING AND SHIPPING PROCEDURES

7.1 L/3 Length Capsule Assemblies

- 7.1.1 The shipping container for each L/3 capsule shall be constructed of 1/2" thick plywood, joined by wood screws with outside dimensions of approximately 24" x 24" x 4". Two pieces of 1-1/2" thick plastic foam sheets or foam rubber shall be fitted inside the box.
- 7.1.2 Each capsule shall be completely constructed, and inspected in accordance with Assembly Procedures and Drawing PF 10650.
- 7.1.3 Thermocouples shall be coiled in a circle approximately 12" in diameter.
- 7.1.4 Each capsule shall be fastened to one foam block with a minimum of (2) plastic covered tie down wires.
- 7.1.5 Each thermocouple coil shall be fastened to the foam block with a minimum of (2) plastic covered tie down wires.
- 7.1.5 If plastic foam is used, it shall be hollowed out to fit the contour of each capsule.

7.2 "L" Length Capsule Assemblies

- 7.2.1 The shipping container for each "L" capsule shall be a metal drum that meets the requirements of ICC 17H and shipment shall be fissile Class III.
- 7.2.2 Each capsule shall be completely constructed and inspected in accordance with Assembly Procedures and Drawings PF 10650 or 10651.
- 7.2.3 Thermocouples shall be coiled in a circle approximately 12" in diameter.
- 7.2.4 Each capsule shall be wrapped in foam rubber and wired to a rigid board in a minimum of four places.
- 7.2.5 The thermocouple coil shall be cushioned with foam rubber or plastic and tied to the board with a minimum of 3 tiedowns.
- 7.2.6 The board and capsule assembly shall be placed in a metal drum and the empty space filled with suitable packing material.

7.3 Shipping

- 7.3.1 Capsules shall be shipped in accordance with applicable D.O.T. regulations and in compliance with AEC License SNM-951.

APPENDIX H

Tube to End Cap Weld Cracking Analysis and Repair Development

Weld Defect Location and Type

In the production of the first capsule tube to end cap welds (capsule 901-510A) the visual penetrant inspection revealed the presence of small cracks running in both the longitudinal and transverse directions. Figure H-1 shows a longitudinal crack located in the center of the weld bead and Figure H-2 shows a typical transverse crack running from the weld center towards the edge.

Sample welding demonstrated the cracks could be duplicated using the lot of 304L stainless steel purchased for this program. Metallographic examination of many sample welds both in tube to end cap joints and in bead on tube welds revealed the maximum crack depth of .67 mm (.0265") in a longitudinal crack. Photos of typical cross sections are shown in Figures H-3, -4, -5, and -6. In no case did mass spectrometer helium leak testing indicate that the cracks were continuous through the welds.

Weld Defect Analysis

Metallographic examination of capsule tube and end cap materials revealed nothing abnormal in the metal structure. Chemical and spectral analysis were also performed and the results indicated the materials were as certified and within the composition range for 304L stainless steel. The nickel content of the tube material was near the high limit however (11.25%) indicating a strong austenitic tendency would be present during weld metal solidification.

The welding procedure that had been developed for the capsule tube to end cap joint employed two passes. The first pass at high energy to produce the desired penetration had a tendency to leave a small undercut on the weld edge at the tube. The second pass was at low energy and located off-center to smooth out this possible undercut. The original weld development specimens had been produced from 304L stainless steel, but from a different heat of material than the production lot. Inspection had indicated these development welds were free of defects.

The cracking tendency when using the production lot of tube material indicated the problem was composition related. The high nickel content noted previously results in the weld zone being more strongly austenitic than other heats of 304 or 304L stainless steel. It is widely recognized that formation of some ferrite during solidification is an important factor in avoiding hot cracking. Thus, it was concluded that the most probable cause of the hot cracking problem was the more austenitic composition of the capsule tube material, aggravated by the increased stresses developed by the cosmetic pass.

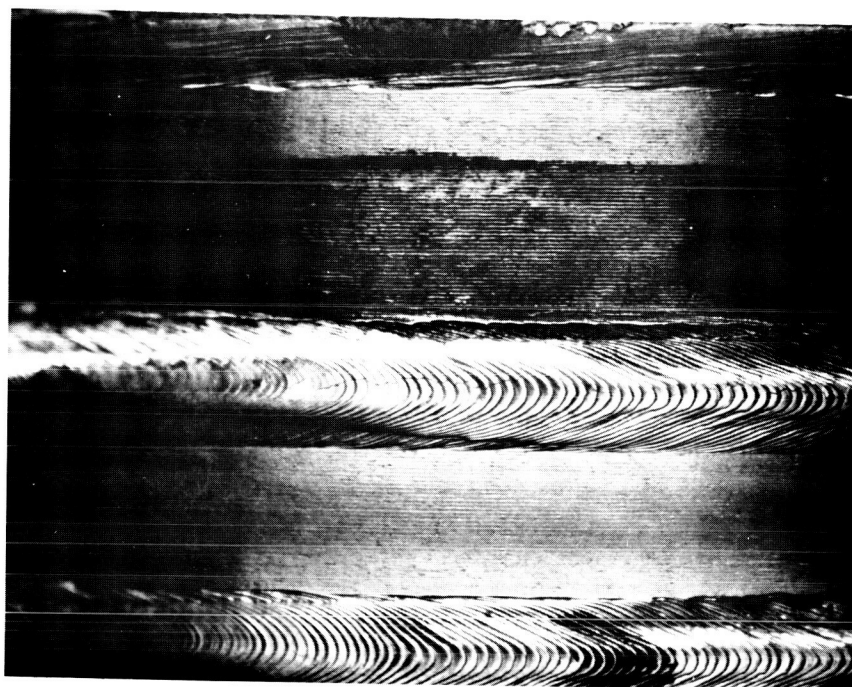


Figure H-1. Typical Circumferential Weld Crack 12X

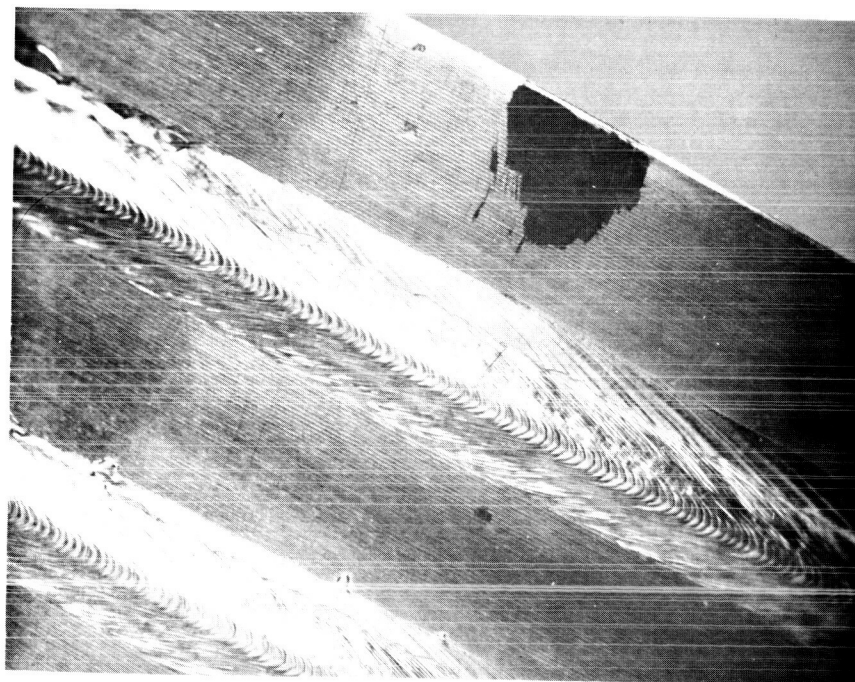


Figure H-2. Typical Transverse Weld Crack 12X

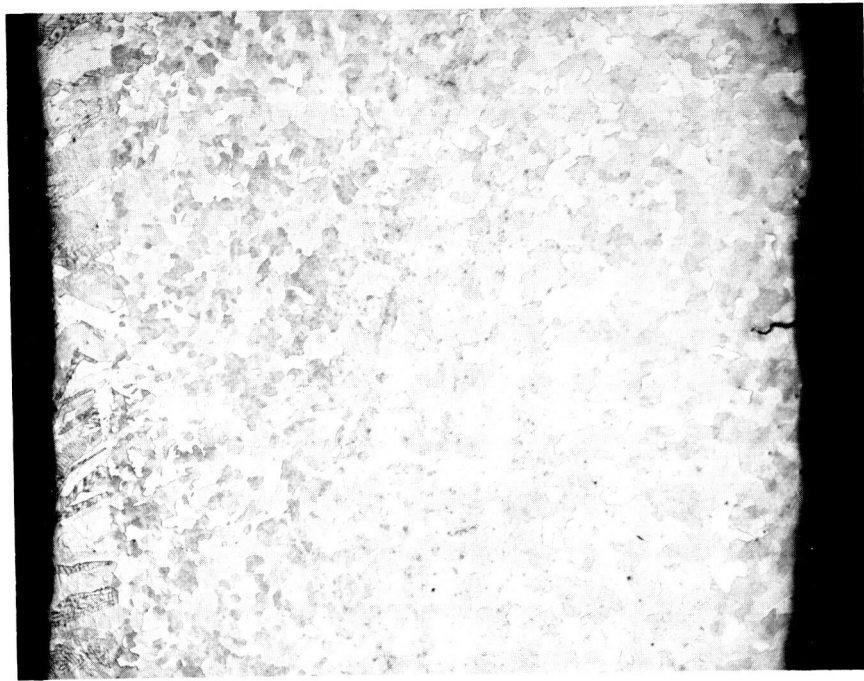


Figure H-3. Typical Transverse Weld Bead Crack 50X



Figure H-4 Typical Transverse Weld Bead Crack 50X



Figure H-5. Typical Circumferential Weld Bead Crack 50X



Figure H-6. Typical Circumferential Weld Bead Crack 50X

Repair Procedure Development

The objective of this procedure development was to repair end cap welds, eliminating the cracking, without disturbing the high purity helium backfill of the capsule. As noted previously, evaluation of many defects had indicated a maximum depth of approximately .67 mm (.026"). Thus the procedure was designed to remove these defects and replace with standard stainless steel weld filler wire to eliminate subsequent cracking problems.

A groove .82 mm (.032") wide by .76 mm (.030") deep was ground in the center of the weld bead. A .82 mm (.032") diameter 308 stainless steel filler wire was spot welded into the groove with a capacitor discharge welder. The filler wire was then fused into the weld by the electron beam process.

Figure H-7 shows the grinding disc attached to an X-Y table while the capsule is mounted in the rotating Sciaky welding fixture. Figure H-8 shows the grinding disc and a partially grooved out weld. Figure H-9 shows the filler wire being spot welded into position and the joint area finally prepared for E. B. welding is shown in Figure H-10.

Prior to the actual repair, two simulated capsules were constructed to the same wall thickness and O. D. as production assemblies and sealed at atmospheric pressure. A repair weld was made on both end cap welds and one bead on tube weld on each of these two sample capsules. The parameters employed are shown in the attached weld procedure sheet. All six of these repair welds were made without losing pressure from inside the capsules. In addition, cracking was eliminated. Figure H-11 is a typical cross section of a repair weld while Figure H-12 is a typical axial view through a repair weld.

This repair procedure was applied successfully where cracking occurred on "L" length capsules. All inspection methods indicated that the welds were sound.

Modified Weld Procedure

All capsule tubes had been machined at the time the weld cracking problem was observed. The machining of these parts represented a considerable investment in time and money. Thus a new weld procedure was developed which made possible the continued use of these parts without the necessity of weld repairs.

The basic objective of the new procedure was to introduce 308 stainless steel filler material into the fusion zone. Weld repair techniques previously discussed had demonstrated that this could resolve the cracking problem associated with the composition of the tube material. Thus it was decided to preplace the filler as part of the basic weld procedure in a manner which would require little or no machining of existing parts.

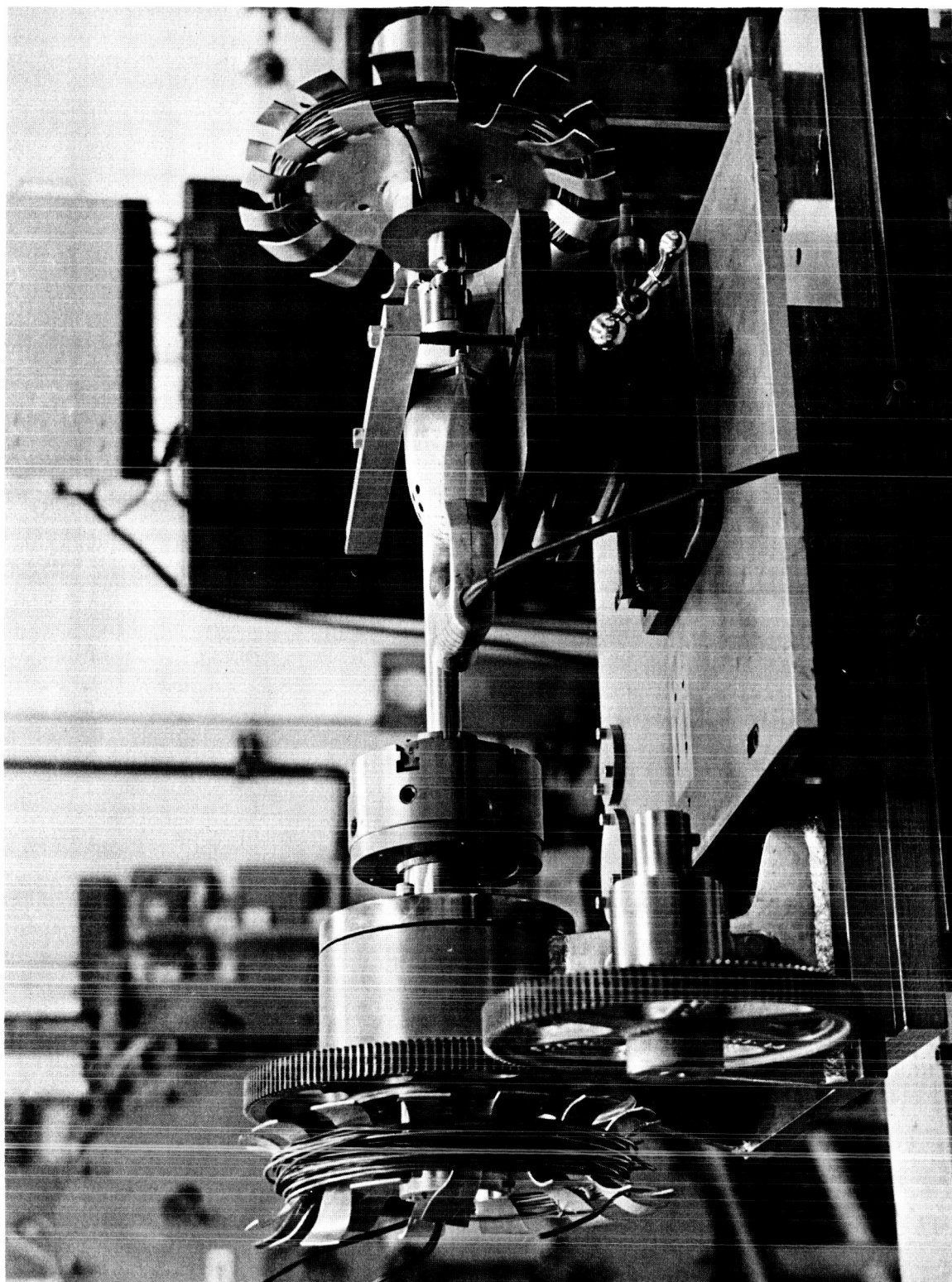


Figure H-7. Grinding Wheel for Grooving Out Capsule Welds for Repair

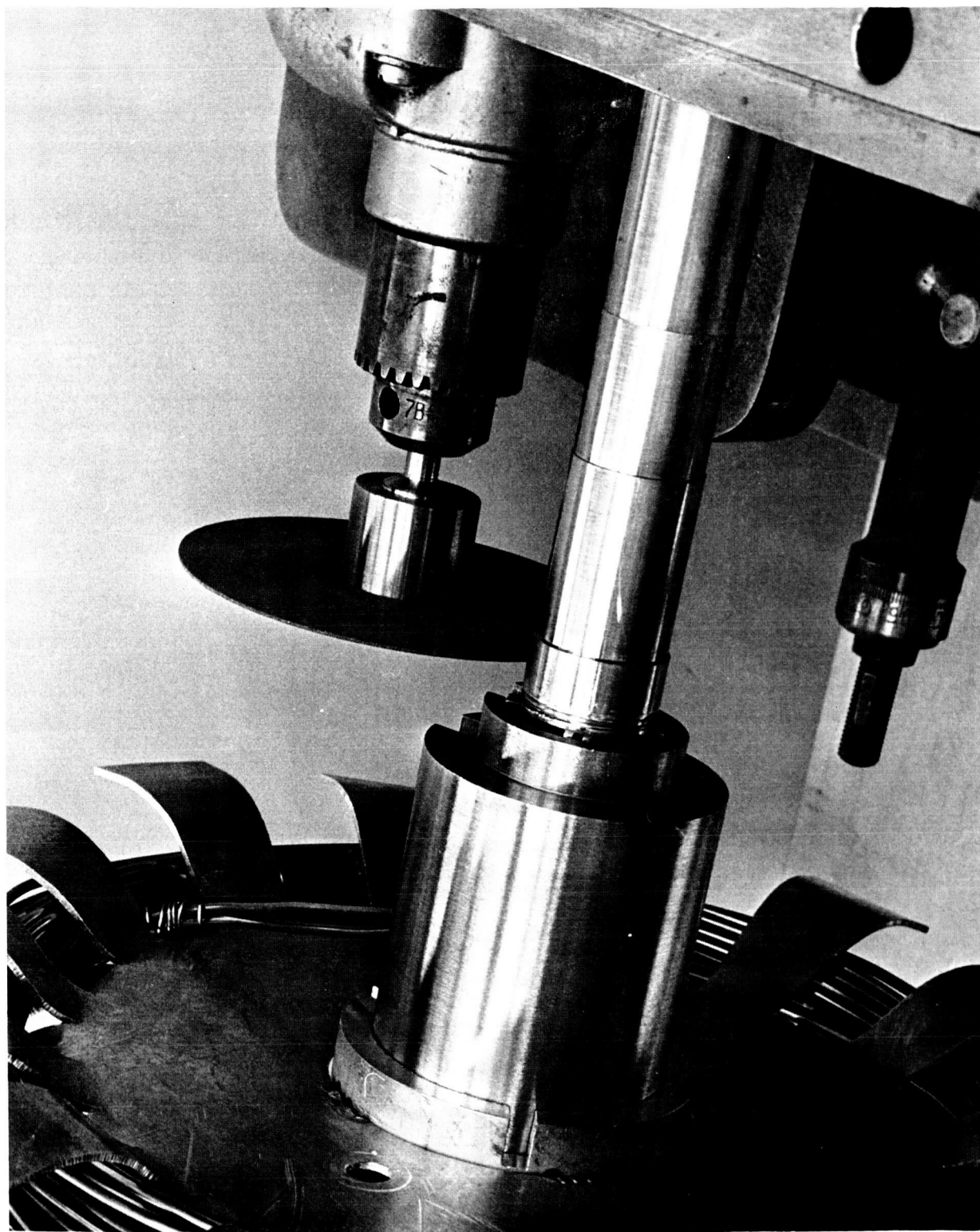


Figure H-8. Grinding Wheel Grooving Capsule Weld

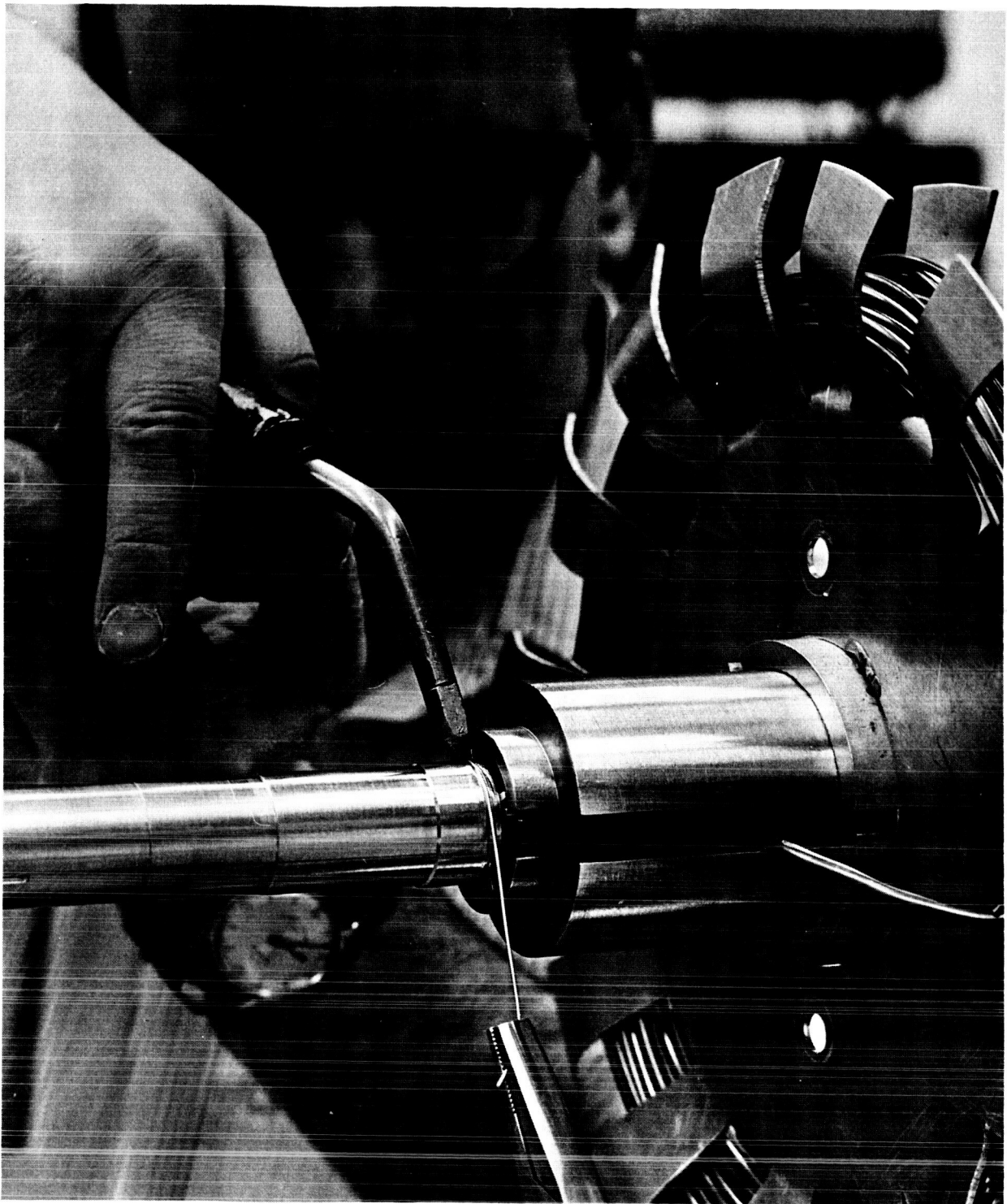


Figure H-9. Spot Welding 308 Stainless Steel Filler Wire into Capsule Weld Groove

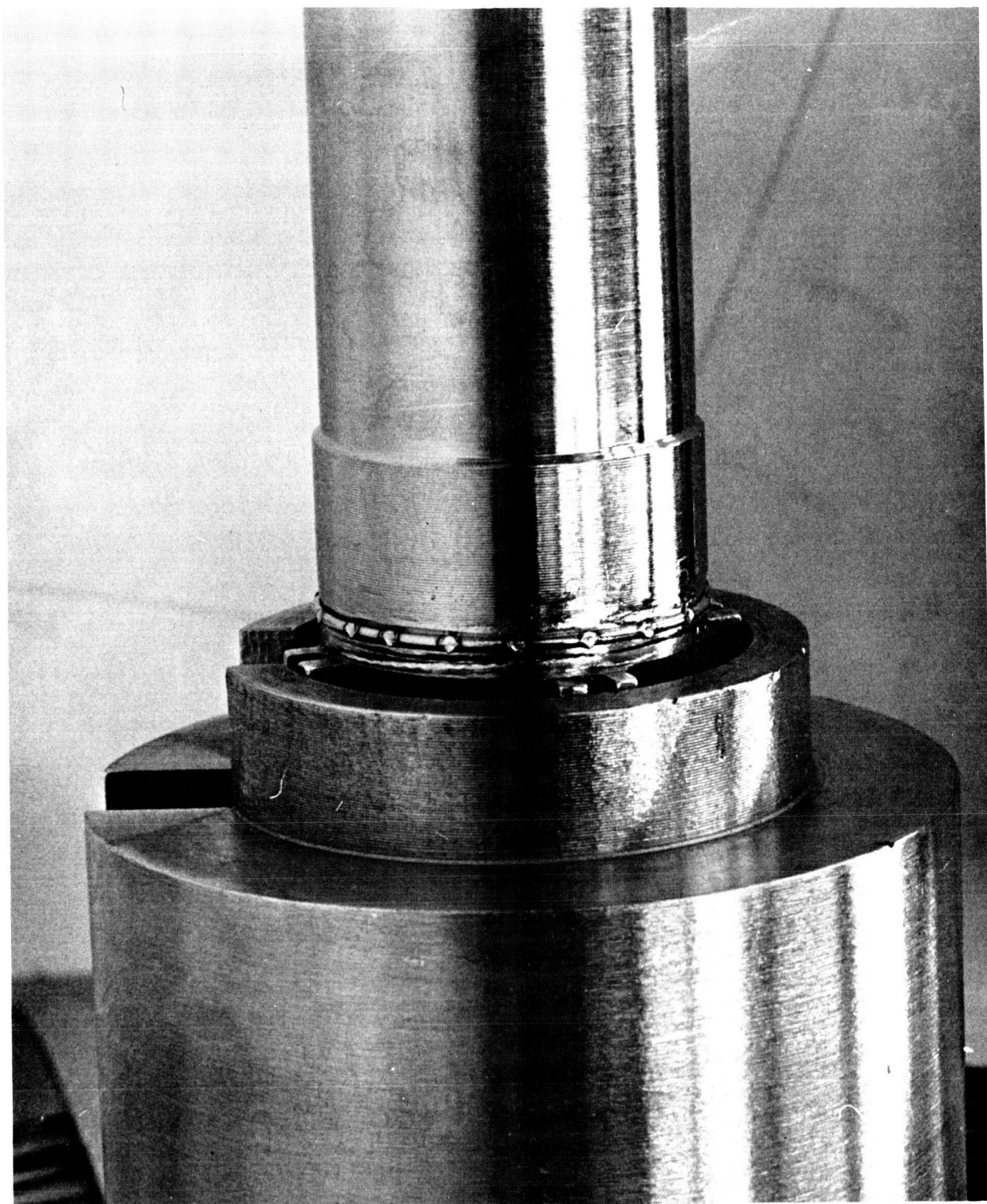


Figure H-10. Capsule Weld with 308 Stainless Steel Filler Wire in Place Ready for E.B. Weld

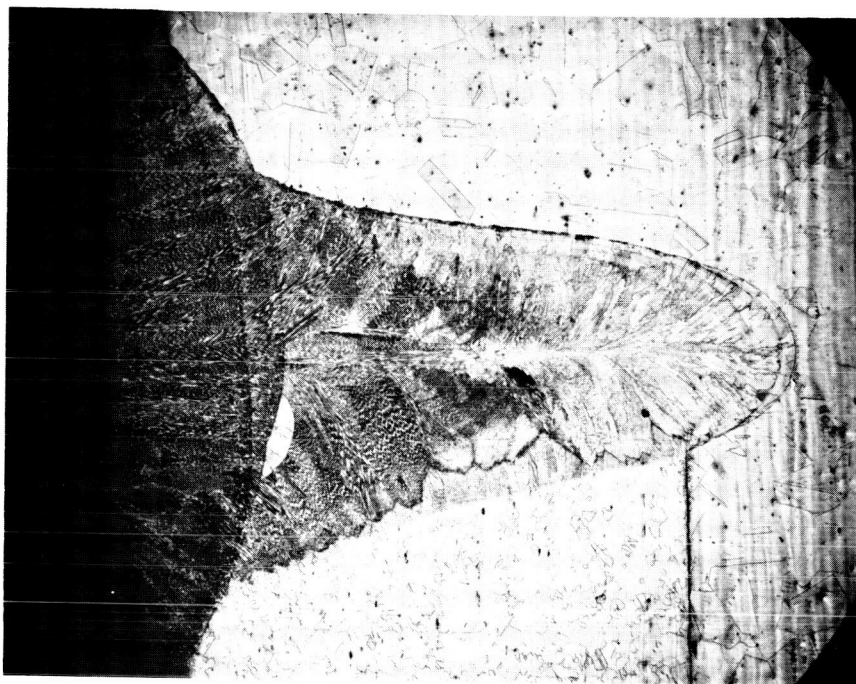


Figure H-11. Cross Section of Typical Weld Repair 40X

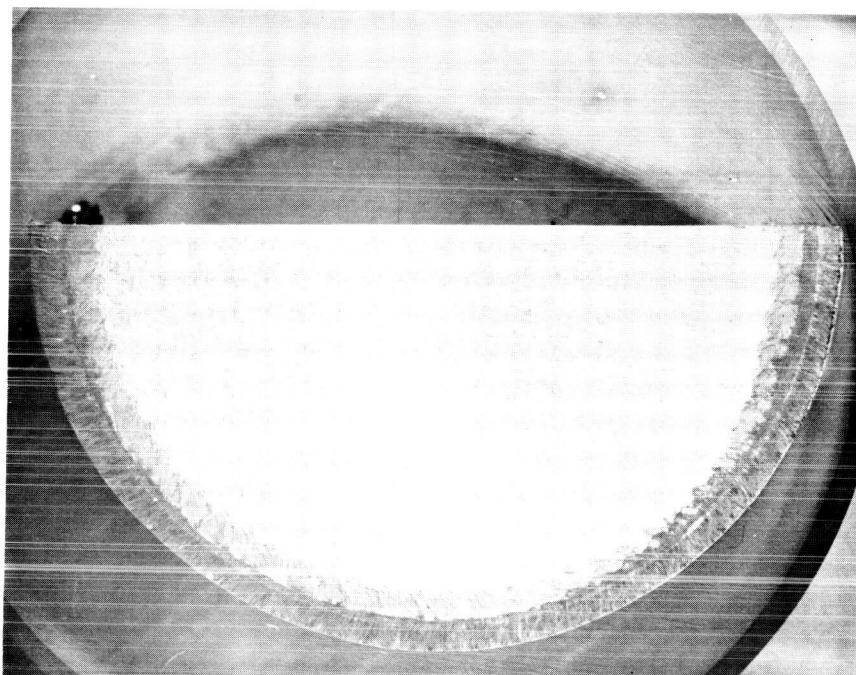
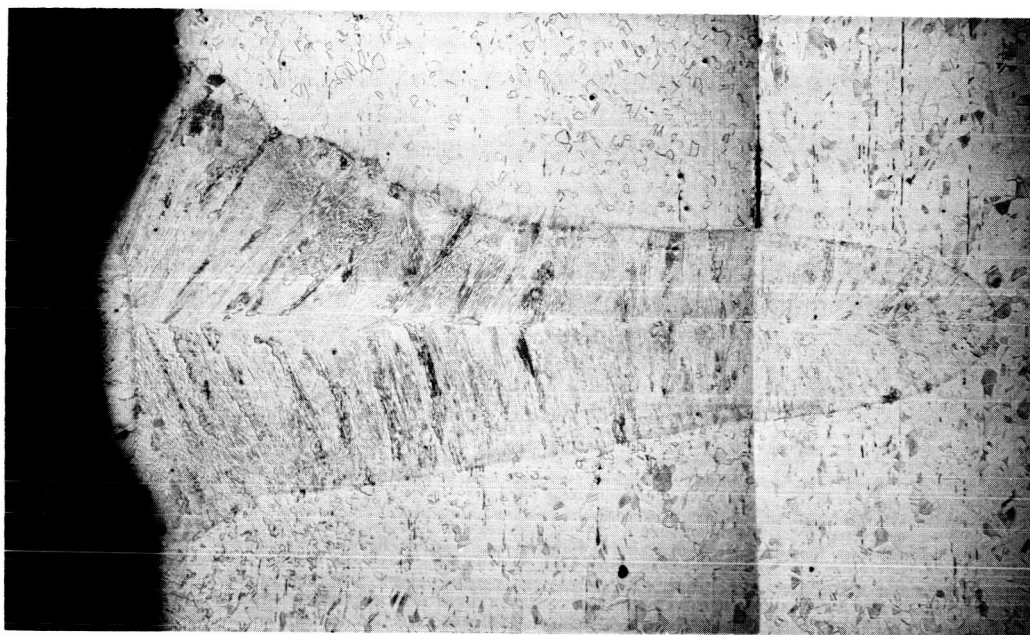


Figure H-12. Axial View Through Typical Weld Repair 4X

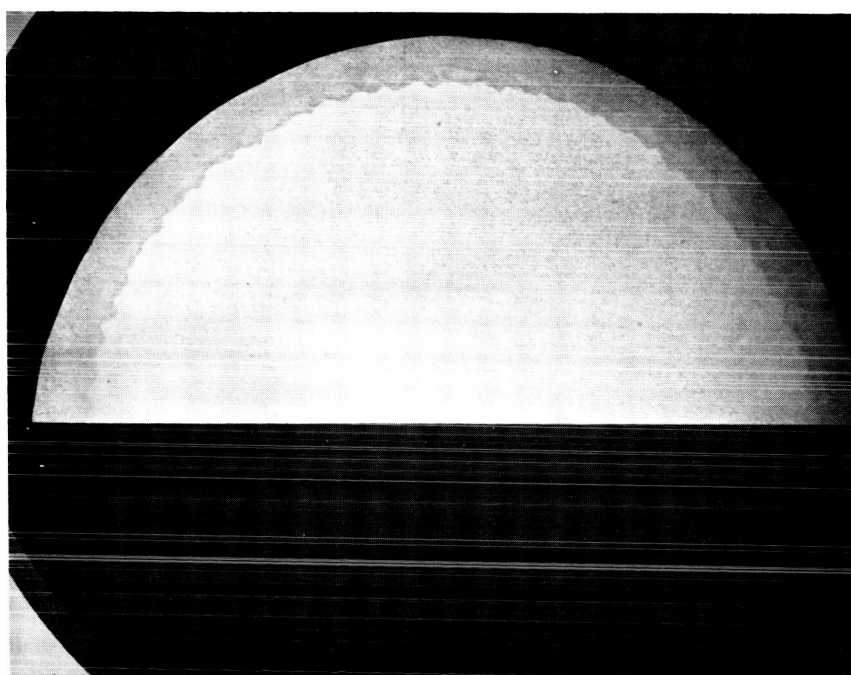
Stainless steel filler, 308 composition, is generally not available in forms other than wire. Thus, to achieve the desired preform shape the filler was first deposited by the tungsten arc process on the outer surface of a piece of stainless steel pipe of appropriate diameter. Multiple passes built this layer to approximately 3.17 mm (.125"). From this deposited material, washers .38 mm (.015") thick were machined to fit in the end cap to tube weld joint.

Evaluation of welding parameters indicated that the same basic settings used without the filler still produced the desired configuration when the preform was used. Figures H-13 and H-14 are transverse and longitudinal cross section of a typical sample weld of this type. In no case were cracks observed in sample or production welds employing the 308 stainless steel preformed insert.



40X

Figure H-13. Transverse Section of Sample Capsule Tube to End Cap Weld Employing a .38 mm (.015") thick 308 SS Preplaced Washer to Prevent Hot Cracking



4X

Figure H-14. Longitudinal View of Weld in Figure H-13

APPENDIX I

Thermocouple Well Contamination

THERMOCOUPLE WELL CONTAMINATION

Description of the Problem

Design of the "end cap" and "fuel center" thermocouples used to sense fuel pin temperature in the irradiation test capsules made use of an integral tantalum well in the hot zone. This permitted the sensing end of the thermocouple to be in intimate contact with the fuel pin without contaminating the T-111 clad. Figure 1-1 is a schematic representation of these thermocouples.

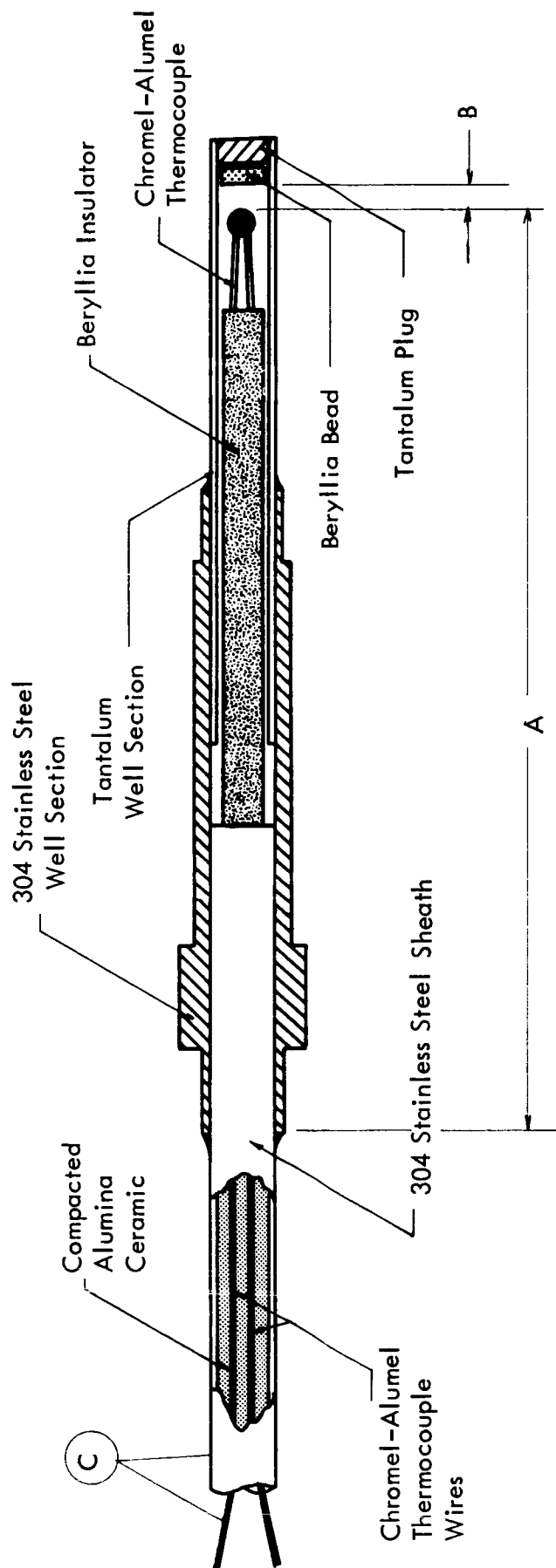
Inspection procedures for each thermocouple included a thermal cycle and calibration test in which the thermocouple hot end was cycled through its highest operating temperature four times and calibrated against a known standard at four temperature levels. These inspection procedures also included destructive examination of a sample of each type thermocouple after their thermal cycle calibration test.

As a part of the metallurgical analysis, micro-hardness tests performed on the tantalum section of a thermocouple well detected an increase in hardness. Sectioning of five additional thermocouples previously tested confirmed an apparent contamination originating from the interior of the well during the thermal cycle calibration test. The highest temperature regions were affected to the greatest extent with little or no observable contamination in cold areas. Hardness values over 600 DPH were measured at the I. D. of two thermocouples while three had values ranging from 150 to 338 DPH. The original, recrystallized tantalum tubing had a hardness of approximately 80 DPH. One thermocouple showed no evidence of contamination; however, this unit had been tested at 816°C (1500°F) rather than the 996-1177°C (1825-2150°F) used for the others. The two thermocouples with the highest hardness values had visible contamination of the internal surfaces in the hot zone when examined metallographically. This was not so on thermocouples with lower hardness values. Assemblies examined were both 2-wire and 4-wire types from Phase III and a 2-wire 1.6 mm (1/16") diameter thermocouple from Phase II. Results of all hardness testing are listed in Table 1-1.

Chemical analysis of (3) of the tantalum thermocouple wells revealed a large increase in oxygen content in all samples (see Table 1-2). Hydrogen content increased in one sample while a significant amount of nitrogen was observed in TC No. 8 which had an air leak in the sheath. No quantitative value was determined for nitrogen because of the small sample size, but it was concluded that at least as much nitrogen was present in TC No. 8 as oxygen.

A spectral analysis using a laser instrument was also performed on thermocouple samples and raw material samples. No significant difference was noted between these samples. There was no sign of any metallic contamination such as carbon, iron, or aluminum.

It was concluded from these data that the major contaminating agent was oxygen. Nitrogen appeared to be a significant factor in TC No. 8, but this may have been due to the hole in the sheath above the hot zone and is not typical of the other thermocouples.



- A - Insertion Depth _____
- B - Thermocouple End Clearance _____
- C - Thermocouple Insulation Resistance _____

Figure I-1. Thermocouple Hot Zone Construction

TABLE I-1

HARDNESS MEASUREMENTS, THERMOCOUPLE TANTALUM WELL
(AVERAGES IN DPH)

TC No. and Description	Area Tested	Inside Surface	Center	Outside Surface
No. 1 2.4 mm (3/32") 2-wire L-I Inlet Fuel Center No. 6 (4E)	Tube Near Plug Tube Away from Plug Near Bi-metal Joint	162 164 122	163 180 110	159 175 95
No. 3 2.4 mm (3/32") 2-wire L/3 Inlet Fuel Center No. 2 (4B)	Tube Near Plug Tube Away from Plug Tube Near Bi-metal Joint	285 338 67	267 172 117	272 146 98
No. 8 2.4 mm (3/32") 2-wire L/3 Inlet Fuel Center No. 2 (4B)	Plug Tube 1.27 mm (.050") from Plug Tube 10.2 mm (.4") from Plug Tube 20.3 mm (.8") from Plug	602 577 614 671	127 550 488 260	120 535 333 140
No. 0019 Phase II 1.6 mm (1/16") 2-wire	Plug Tube 1.27 mm (.050") from Plug Tube 10.2 mm (.4") from Plug Tube 20.3 mm (.8") from Plug	219 193 170 155	119 231 206 146	97 196 178 129
No. 49 2.4 mm (3/32") 4-wire L-I Inlet End Cap No. 5 (4D)	Tube Near Plug Tube Away from Plug	622 312	410 152	259 116
No. 50 2.4 mm (3/32") 4-wire L-I Inlet End Cap No. 5 (4D)	Plug Tube Near Plug Tube Away from Plug Tube Near Bi-metal Joint	94 84 84 97	108 101 94 98	93 94 98 96
TC Well Processed Ready for Assembly	Plug Tube Near Plug Tube Away from Plug	80 92 77	87 97 98	85 82 84

TABLE I-2

CHEMICAL ANALYSIS OF THERMOCOUPLE WELLS
BY THE VACUUM FUSION TECHNIQUE

SAMPLE	HYDROGEN (ppm)	OXYGEN (ppm)	NITROGEN (ppm)
Raw Material	< 1	13	None
	< 1	4.5	Detected
TC No. 3	3	210	Small
	< 1	970	Trace
TC No. 0019	10	610	None
	28	970	Detected
TC No. 8	1	190	Significant
	2	400	Amount

Experiment to Define Contamination Source

The most probable source of oxygen in the closed thermocouple system is the long stainless steel sheathed, compacted ceramic thermocouple lead. Other possibilities include the hard-fired ceramic located in the hot zone or some unknown factor in the processing. A "Thermocouple Well Experiment" was designed to pin point the source of the oxygen contamination. In this experiment, six thermocouple wells were built, and three of these wells were filled with hard-fired ceramic. All processing was the same as used when building thermocouples. These wells were tested in the thermal cycle-calibration test rig at the same conditions as the thermocouples.

Post-test evaluation included chemical analysis (for nitrogen, oxygen, and hydrogen) of two wells from each group of three and metallographic and hardness examination of the third well from each group. Table I-3 is a summary of the hardness data, and Table I-4 summarizes the chemical analysis.

No substantial hardness increase occurred in these tests indicating that the contamination originates in the stainless steel sheathed thermocouple lead. The only evidence of contamination in the mockup thermocouple wells was the 200 ppm oxygen analysis of sample No. 2. A subsequent analysis from an adjoining area was considerably lower in oxygen, 85 ppm. However, even this lower value is slightly higher than other samples. There was no indication in any of the mockup TC wells of the higher levels of contamination detected in the thermocouples.

Experiment to Define Contaminating Agent

Thermocouple wells previously examined had been at elevated temperature only 4 to 6 hours through the thermal cycle-calibration test sequence. A longer term test was planned to determine the effects of time on the contamination problem and hopefully to provide more definitive information on the actual contaminate.

Three previously constructed thermocouples were selected for a 100 hour high temperature, high vacuum test. These were installed in an ion pumped high vacuum furnace with the tantalum wells extending into the hot zone and the bimetal joint cooled with a molybdenum cooling ring. Thermocouples were tested a total of 118 hours $1177^{\circ}\text{C} \pm 28^{\circ}$ ($2150^{\circ}\text{F} \pm 50^{\circ}$) with 12 thermal cycles between 260°C (500°F) and 1177°C (2150°F). The bimetal joint temperature was monitored and averaged 329°C (625°F) while the sensing ends were at maximum temperature. Pressure was maintained at or below the 10^{-8} torr range throughout the test. Thermocouple insulation resistance increased from 1×10^{11} at the beginning of the test to $>8 \times 10^{12}$ (infinite reading at megohmmeter at 500 V) at the end of the test.

Post-test examination included metallographic and hardness evaluation of one of the thermocouples (TC No. 5) and chemical analysis for nitrogen, oxygen, and hydrogen of the other two (TC Nos. 4 and 19). Note: TC No. 19 is not to be confused with TC No. 0019

TABLE I-3
Hardness Measurements, Thermocouple Well
(DPH)

Sample No. and Description	Area Tested	Inside Surface	Center	Outside Surface
No. 1 - Mockup TC with 2-hole alumina	Plug	94	97	101
	1.27 mm (.050") from plug	107	108	96
	12.7 mm (1/2") from plug	88	107	101
	38.1 mm (1-1/2") from plug	81	107	100
	63.5 mm (2-1/2") from plug	97	103	102
No. 7 - Mockup TC Empty	Plug	86	84	84
	1.27 mm (.050") from plug	104	101	93
	12.7 mm (1/2") from plug	78	100	101
	38.1 mm (1-1/2") from plug	91	104	103
	63.5 mm (2-1/2") from plug	87	102	107

TABLE I-4
Chemical Analysis of Thermocouple Wells

Sample No. and Description	Hydrogen (ppm)	Oxygen (ppm)		Nitrogen (ppm)
No. 2 Mockup TC with 2-hole alumina	3	1st	200	10
		2nd	85	
No. 3 Mockup TC with 4-hole alumina	<.4		59	13
No. 6 Mockup TC Empty	.7		67	29
No. 8 Mockup TC Empty	8		44	26
Raw Material (cleaned and annealed)	<.4		58	28

which was analyzed and discussed previously. Hardness data for thermocouple No. 5 is listed in Table I-5, and the chemical analysis of thermocouples No. 4 and 19 are listed in Table I-6. Figure I-2 is an axial profile of thermocouple No. 5 average hardness with the approximate area identified from which each chemical sample was taken.

A number of observations were apparent from the data obtained.

1. Hardness values across the wall in any axial position were relatively constant compared to the short term tests.
2. Wide differences in hardness values occur axially along well length.
3. Nitrogen, oxygen, and hydrogen content varies with axial location.
4. The contaminating agents were both oxygen and nitrogen with the latter playing the major role. This is opposed to the conclusion reached in the short term tests which indicated that oxygen was the major contaminate.
5. The large hardness peak at the beginning of the hot zone indicates that the contaminating agents arrive at the hot zone at a very slow rate.
6. The high hardness peak near the plug end could have been caused by the initial heatup profile when the well was comparatively rich in contaminants.

Figures I-3, -4, and -5 are microphotographs of three areas along the well from TC No. 5. Figures I-3 and -4 were photographed 12.7 mm (1/2") and 38.1 mm (1-1/2") from the plug end and show nothing unusual in the structure. Figure I-5 was taken 66.5 mm (2-5/8") from the plug end in the area of the large hardness peak (see Figure I-2). This area contains several precipitates, probably oxides or nitrides (or both) scattered in grain boundary locations.

Conclusions

These tests performed have demonstrated that residual contaminants remain in the thermocouple system after processing. These contaminants are basically nitrogen and oxygen, and they originate in the stainless steel sheathed-compacted ceramic thermocouple lead. The rate of TC well contamination is comparatively rapid in the first few hours of high temperature operation then diminishes with time. This phenomenon has occurred in all of the thermocouples built to the same design and is not unique with the Phase III capsule program.

Initial processing in early stages of thermocouple construction is probably a greater factor in this residual contamination and the rate of its release than subsequent processing, which can be more closely controlled. Means for removing these residual active gases without an extensive investigative effort were not apparent. Based on these findings and the success of similar thermocouples that had successfully operated for long periods in reactor test, it was recommended that the capsule and thermocouple construction continue as scheduled using present processing techniques.

TABLE I-5
TC No. 5 Hardness Data (DPH)

Distance From Plug End	Inside Surface	Center	Outside
Plug	236	203	198
.52 mm (.020")	272	303	291
1.27 mm (.050")	286	324	340
6.3 mm (1/4")	298	307	294
12.7 mm (1/2")	480	488	513
19.1 mm (3/4")	335	375	364
25.4 mm (1.0")	207	260	263
31.8 mm (1-1/4")	195	244	242
38.1 mm (1-1/2")	210	234	232
44.5 mm (1-3/4")	236	254	256
50.8 mm (2.0")	310	321	328
57.1 mm (2-1/4")	454	454	443
63.5 mm (2-1/2") (.020")	802	827	813
63.5 mm (2-1/2")	819	811	822
70.0 mm (2-3/4")	801	806	813
76.2 mm (3.0")	425	414	396
82.5 mm (3-1/4")	101	100	112

TABLE I-6

Chemical Analysis of Thermocouples No. 4 and 19 After 100 Hour Test

Sample No. and Description	Location	Hydrogen (ppm)	Oxygen (ppm)	Nitrogen (ppm)
(No. 4) TC No. 4	Plug End	3	40	760
TC No. 4	Bimetal Joint End	9	250	460
(No. 19) TC No. 19	Plug End	3	50	~700
TC No. 19	Bimetal Joint End	9	250	920
Raw Material Cleaned and Annealed	--	<.4	58	28

Note: Oxygen and hydrogen were analyzed by the vacuum fusion method and nitrogen by the KJELDAHL method. Confidence level of all determinations is within $\pm 10\%$.

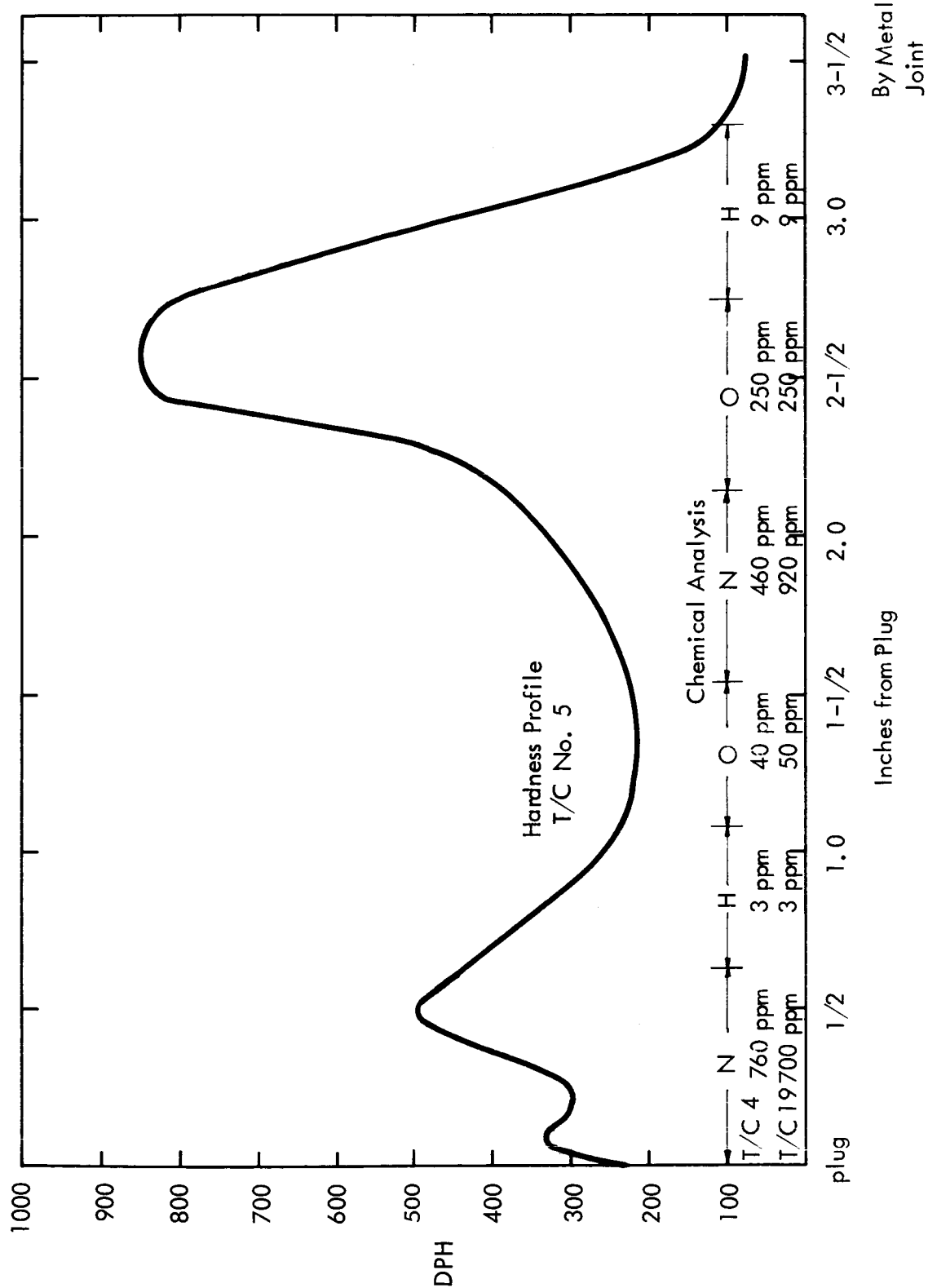
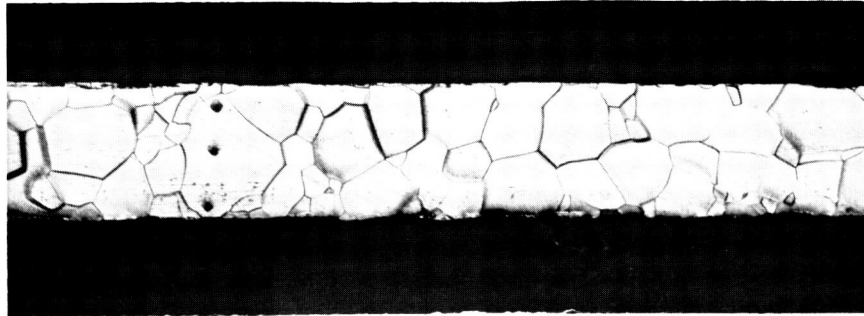


Figure I-2. Thermocouple Well Data from 100 Hour Test

ID

100X



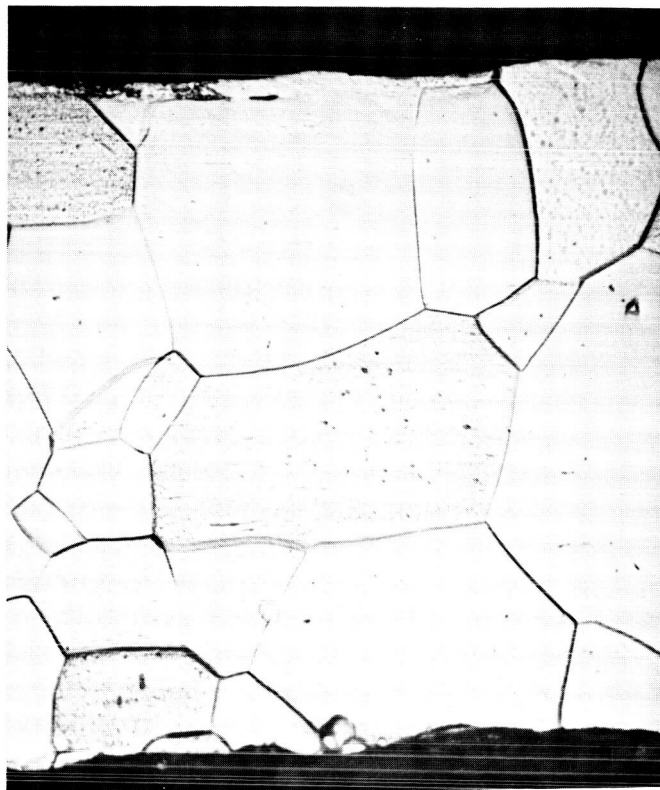
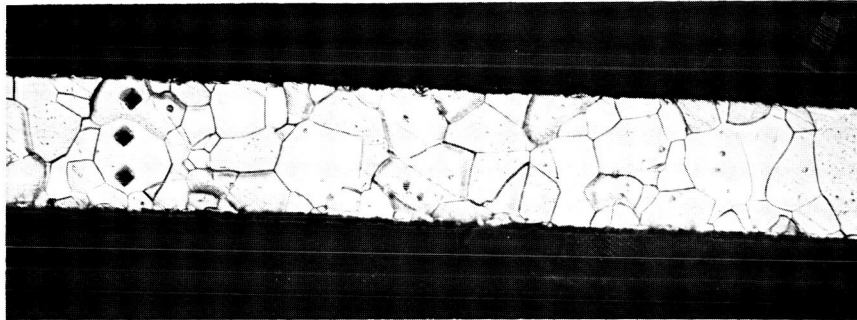
OD

500X

Figure I-3. TC No. 5 Thermocouple Well 12.7 mm (1/2") from plug end.

ID

100X



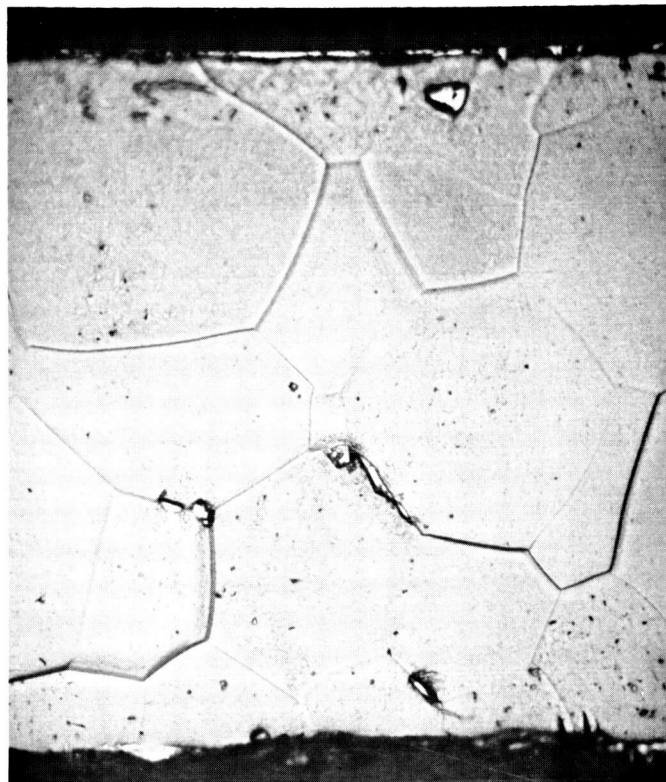
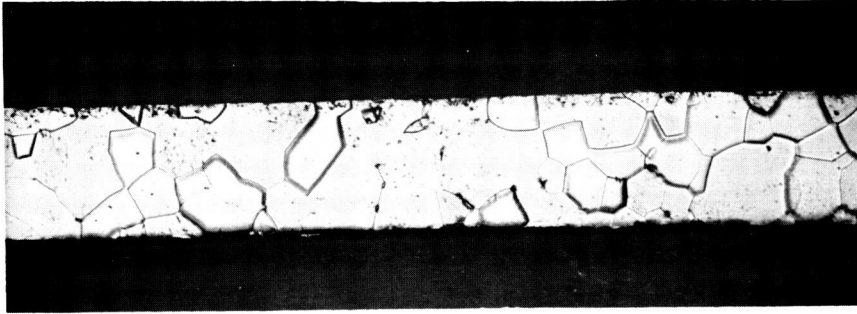
OD

500X

Figure I-4. TC No. 5 Thermocouple Well 38.1 mm (1-1/2") from plug end.

ID

100X



OD

500X

Figure I-5. TC No. 5 Thermocouple Well 66.8 mm(2-5/8") from plug end.

APPENDIX J

CAPSULE RUST INVESTIGATION

Visual examination of capsules 901-514A, B, and C and 901-518A and B revealed the presence of surface rust in the end cap areas. This condition was detected after receipt of these units at Plum Brook. The capsules were returned to WANL so that the necessary steps could be taken to isolate the cause and resolve the means for removal.

A complete review of handling procedures used by WANL during fabrication and final cleaning of the aforementioned capsules revealed no known source for surface contamination which would result in subsequent rusting. All containers brushes, etc. were either nylon, glass, or 304 stainless steel. Handling of all component parts after cleaning was performed with clean gloves. All unused end caps and tubes machined from the same lots of material and at the same time as those that discolored were examined. No rust could be detected visually at 30X magnification nor did chemical spot check reveal the presence of free iron on the surface of the stainless steel parts.

The problem was reviewed with knowledgeable authorities both within Westinghouse Electric and at the material supplier (Allegheny Ludlum). It was determined that the observed rusting was most probably superficial and would not be progressive or detrimental to the stainless steel upon continued exposure in a water-air environment.

A test program was performed on end cap and tube material to determine if rusting would occur under high humidity (100% at 120°F for 24 hours) conditions and the merit of passivation cycles in preventing the oxidation. Cleaning cycles of the stainless steel test specimens consisted of either ultrasonic degreasing in oxyelene or degreasing plus 30 minutes in a room temperature/5% HNO_3 solution, or mechanically cleaned using a stainless steel brush and 320 grit silicon carbide abrasive paper followed by swabbing with a 50% HNO_3 solution at room temperature.

The results of the tests indicated that the rust could be removed and that it was indeed superficial. The following procedure was used to remove the rust from capsules 901-514 A, B, and C, and 901-518 A and B.

- A. Capsule end caps were mechanically cleaned using a stainless steel brush followed with 320 grit silicon carbide paper.
- B. Degreased by swabbing with oxyelene and grain alcohol.
- C. End cap areas swabbed using a 50% HNO_3 solution followed by distilled water rinse. (Note: Wall thermocouples are masked prior to acid swabbing.)
- D. Capsules exposed in a 100% humidity environment at 120°F for 24 hours to confirm removal of rust.

To prevent the reoccurrence of the problem, it was further advised that in the future all stainless steel capsule parts be passivated in accordance with WANL Process Specification 597922-4 before assembly. A copy of this specification is attached as part of this Appendix.

INFORMATION CATEGORY

UNCLASSIFIED

Authorized Classifier Date



Westinghouse Electric Corporation

Astronuclear Laboratory
P. O. Box 10864
Pittsburgh, Pa. 15236
(Fed. Ident. Code No. 14683)

PROCESS SPECIFICATION 597922
(Not for Publication)

May 3, 1967

STAINLESS STEEL, 300 SERIES - TREATMENT OF

1. SCOPE

This specification covers requirements for treatment of austenitic stainless steel (300 series) parts and assemblies, designated as follows:

<u>Designation</u>	<u>Description</u>
597922-1	Annealing for maximum ductility
597922-2	Stress relieving for removal of residual stresses
597922-3	Stress relieving for removal of peak residual stresses
597922-4	Passivation

NOTE: Unless otherwise specified, the following requirements apply to all designations.

2. APPLICABLE DOCUMENTS

The following documents, of the issue in effect, shall form a part of this specification to the extent specified herein.

Westinghouse Safe Practice Data Sheets

3. REQUIREMENTS

3.1 SAFETY: Some of the materials and/or operations required by this specification may be hazardous. The vendor is requested to consult a qualified Safety or Industrial Hygiene Engineer for necessary precautions. If processed by a Westinghouse plant, the Safe Practice Data Sheets shall be consulted to obtain information regarding the nature and properties of any material or processing requirement to avoid accident to employees or damage to equipment.

3.2 PROCEDURES: The detailed requirements for the several designations of Section 1 shall be as specified in the applicable designation or procedure of this specification.

Printed in U.S.A.
POP/cas

PS-597922
Page 1 of 8 Pages

4. QUALITY ASSURANCE

4.1 SURVEILLANCE: The vendor's heat-treating equipment, temperature-control devices, details of the heat-treating procedure, and passivation equipment and control shall be subject to inspection by a Westinghouse Quality Control representative who shall be given all reasonable facilities to determine conformance to the requirements of this specification.

4.2 COMPLIANCE: No change shall be made from this specification, or an approved procedure, without first obtaining the purchaser's approval.

4.3 RECORDS: A report shall be prepared and submitted to the purchaser and cover as a minimum a statement indicating successful compliance with the requirements of this specification, required quality control records, name of operator, date of processing, and the signature of the cognizant quality control representative.

ANNEALING FOR MAXIMUM DUCTILITY

1. GENERAL

These steels, except for 304L, 321 and 347 are subject to injurious carbide precipitation along the grain boundaries in the temperature range of 800 - 1400 F. Heating and cooling operations, especially the latter, shall be carried out quickly through this range, particularly through the upper portion of range. Because of the rapid cooling required, complete freedom from residual stresses is not obtained.

2. CLEANLINESS

The surface of the parts or the assembly shall be free of carbonaceous material such as oil, grease etc. prior to charging in the furnace.

3. HEATING

3.1 A neutral to slightly oxidizing atmosphere shall be used. In no case shall the atmosphere be carburizing.

3.2 The parts or assemblies shall be heated rapidly to, or placed in the furnace at a temperature of 1950 ± 45 F. (See Note). Parts or assemblies shall be separated to permit maximum surface area exposure. The parts or assemblies shall be adequately supported and braced to prevent excessive or undesirable distortion. Bracing shall be of a 300 type series stainless steel, or equivalent.

3.3 Parts or assemblies having a maximum section thickness of 0.125 inch and less shall be soaked at 1950 ± 45 F for five minutes minimum. Parts or assemblies having a maximum section thickness greater than 0.125 inch shall be soaked for a minimum of five minutes for each 0.125 inch of section thickness.

NOTE: Annealing temperatures for 321 and 347 type are as follows:

321 - 1800 ± 45 F

347 - 1900 ± 45 F

4. COOLING

4.1 Parts or assemblies having a section thickness of 0.125 inch and less shall be quickly removed from the furnace and cooled freely in air. The rate of cooling shall not be retarded in any manner while passing through the temperature range of 1400 to 800 F.

4.2 Parts or assemblies having a section thickness greater than 0.125 inch shall be quenched in water to room temperature.

5. CONTROL

5.1 The design and construction of the heating equipment shall be such that the temperature at any point in the working zone shall not vary more than + 25 F from the required heat-treating temperature after the charge has been brought up to temperature.

5.2 A sufficient number of suitable automatic temperature-control devices, properly arranged, shall be provided on all heat-treating equipment to assure adequate control of temperature in all working zones. Automatic controlling and recording instruments shall be used. Thermocouples shall be located in the working zones and adequately protected from contamination by furnace atmospheres by means of suitable protecting tubes.

STRESS RELIEVING FOR REMOVAL OF RESIDUAL STRESSES

1. GENERAL

Unstabilized grades of austenitic stainless steels (all except 321 and 347 type) are not suitable for application in corrosive environments and are incapable of meeting intergranular test or embrittlement standards when subjected to the treatment specified in this procedure. When stress relieving must be accomplished without impairing corrosion resistance, 321, 347 or the 304L type shall be used. Unstabilized grades requiring resistance to intergranular corrosion shall be stress relieved in accordance with 597922-3 of this specification.

2. CLEANLINESS

The surfaces of the parts or the assembly shall be free of carbonaceous material such as oil, grease etc. prior to charging in the furnace.

3. HEATING

3.1 A neutral to slightly oxidizing atmosphere shall be used. In no case shall the atmosphere be carburizing.

3.2 The parts or assemblies shall be placed in the furnace at a temperature of 250 F or less. The parts or assemblies shall be separated to permit maximum surface area exposure. The parts or assemblies shall be adequately supported and braced to prevent any undesirable distortion. Bracing shall be of a 300 type series stainless steel, or equivalent.

3.3 The parts or assemblies shall be heated to 1600 ± 45 F at a rate not exceeding 150 F per hour. Parts or assemblies shall be held at this temperature for two hours per inch of thickness of heaviest section, but for not less than two hours.

4. COOLING

The parts or assemblies shall be cooled in the furnace at a rate not to exceed 150 F per hour. When the mean temperature is 300 F, or lower, the parts or assemblies may be cooled in still air.

5. CONTROL

5.1 The design and construction of the heating equipment shall be such that the temperature at any point in the working zone shall not vary more than ± 25 F from the required heat-treating temperature after the charge has been brought up to temperature.

5.2 A sufficient number of suitable automatic temperature-control devices, properly arranged, shall be provided on all heat-treating equipment to assure adequate control of temperature in all working zones. Automatic controlling and recording instruments shall be used. Thermocouples shall be located in the working zones and adequately protected from contamination by furnace atmospheres by means of suitable protecting tubes.

STRESS RELIEVING FOR REMOVAL OF PEAK RESIDUAL STRESSES

1. CLEANLINESS

The surface of the parts or the assembly shall be free of carbonaceous material such as oil, grease etc. prior to charging in the furnace.

2. HEATING

2.1 A neutral to slightly oxidizing atmosphere shall be used. In no case shall the atmosphere be carburizing.

2.2 The parts or assemblies shall be heated to, or placed in the furnace at a temperature of 775 ± 25 F. Parts or assemblies shall be separated to permit maximum surface area exposure. The parts or assemblies shall be adequately supported and braced to prevent any undesirable distortion. Bracing shall be of a 300 type series stainless steel, or equivalent.

2.3 The parts or assemblies shall be held at temperature for four hours minimum for sections with thickness up to one inch inclusive. Sections with thickness over one inch shall be held an additional four hours, or fraction thereof, for each additional inch of thickness.

3. COOLING

The parts or assemblies shall be furnace cooled to 575 F, or lower, after which they may be air cooled.

4. CONTROL

4.1 The design and construction of the heating equipment shall be such that the temperature at any point in the working zone shall not vary more than ± 25 F from the required heat-treating temperature after the charge has been brought up to temperature.

4.2 A sufficient number of suitable automatic temperature-control devices, properly arranged, shall be provided on all heat-treating equipment to assure adequate control of temperature in all working zones. Automatic controlling and recording instruments shall be used. Thermocouples shall be located in the working zones and adequately protected from contamination by furnace atmospheres by means of suitable protecting tubes.

PASSIVATION

1. CLEANLINESS

Prior to passivation, the surfaces of parts or assemblies shall be free of corrosive products, grease, oil, fluxes, weld spatter, heat-treat scale and all other contaminants that might interfere with the passivation treatment. Cleaning shall be done immediately before passivation, or suitable precautions shall be taken to insure that the surfaces remain clean until they are passivated.

2. PASSIVATION

2.1 Solution: The passivation solution shall consist of nitric acid 20% by volume (specific gravity 1.355) and 80% water by volume.

2.2 Time: The parts or assemblies shall be immersed in the solution at 145 to 155 F for 10 minutes minimum.

NOTE: Caution should be observed, as excessive time may result in part damage.

2.3 Rinsing and Drying: Within 15 minutes after immersion in the above solution the parts or assemblies shall be rinsed in clean hot water and thoroughly dried.

3. WORKMANSHIP

All parts or assemblies being passivated shall be handled in a manner that shall prevent contamination before, during and after treatment.

MANDATORY HIGH-NUMBER CONTRACTOR REPORT DISTRIBUTION

High-Number Contractor Reports must be sent to the following list of recipients. The number of copies to be sent to each is indicated in parentheses.

<u>Recipient</u>	<u>Address</u>
Concerned NASA Lewis program manager (3 minimum)	NASA-Lewis Research Center Attention: Robert J. Galbo (M.S. 1142-1) Plum Brook Station Sandusky, Ohio 44870
Concerned NASA Lewis procurement manager (1)	NASA-Lewis Research Center Attention: L.W. Schopen (M.S. 500-206) 21000 Brookpark Road Cleveland, OH 44135
Patent counsel (1)	NASA-Lewis Research Center Attention: N. T. Musial (M.S. 500-311) 21000 Brookpark Road Cleveland, OH 44135
NASA Headquarters technical information abstracting and dissemination facility (10)	NASA Scientific and Technical Information Facility Attention: Acquisitions Branch P. O. Box 33 College Park, MD 20740
Lewis Library (2)	NASA-Lewis Research Center Attention: Library (M.S. 60-3) 21000 Brookpark Road Cleveland, OH 44135
Lewis Management Services Division (1)	NASA-Lewis Research Center Attention: Report Control Office (M.S. 5-5) 21000 Brookpark Road Cleveland, OH 44135
NASA Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135	G.M. Ault/M.S. 3-13 (1) S.J. Kaufman/M.S. 49-2 (1) M.F. Valerino/M.S. 49-2 (1) A.F. Lietzke/M.S. 49-3 (1) J. Slaby/M.S. 49-3 (1) B.L. Siegel/M.S. 49-3 (1)

NASA Lewis Research Center A.B. Davis/M.S. 1141-1 (1)
Plum Brook Station R. Stein/M.S. 1142-1 (1)
Sandusky, Ohio 44870 J. Morley/M.S. 1141-1 (1)

Oak Ridge National Laboratory J.L. Scott
Oak Ridge, Tennessee 37830

Aerojet General Corporation
P.O. Box 296
Azusa, California 91702
Attn: Technical Librarian (1)

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60440
Attn: E.N. Pettitt (1)

General Electric Company
Nuclear Energy Division (MC-328)
P.O. Box 1131
San Jose, California 95108
Attn: Aileen Thompson (1)

NASA Manned Spacecraft Center
Houston, Texas 77058
Attn: Librarian (1)

U.S. Atomic Energy Commission
P.O. Box 62
Oak Ridge, Tennessee 37830
Attn: Technical Information Service Ext. (1)

Westinghouse Electric Corporation
Bettis Atomic Power Lab
West Mifflin, Pa. 15122
Attn: H.R. Warner (1)

Gulf Oil Corporation
P.O. Box 608
San Diego, California 92112
Attn: E. Fisher (1)
 L. Yang (1)
 M.H. Merrill

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103
Attn: J.F. Mondt (1)

NASA Headquarters
Washington, D.C. 20546
Attn: NS-1/J.J. Lynch (1)
 NS-1/P.R. Miller (1)

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
Attn: W. Chubb (1)
D.L. Keller (1)
Dr. H.W. Russell (1)

Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87544
Attn: Report Librarian (1)